A TREATISE

ON

ENGINEERING FIELD-WORK:

CONTAINING

PRACTICAL LAND SURVEYING FOR RAILWAYS, &c.

WITH THE THEORY, PRINCIPLES, AND

PRACTICE OF LEVELLING,

AND THEIR

APPLICATION TO THE PURPOSES OF CIVIL ENGINEERING.

ALSO

PARISH AND SUBTERRANEAN SURVEYING,
WITH SECTIO-PLANOGRAPHY,

AND

EVERY INFORMATION NECESSARY TO BE KNOWN IN THE ELEMENTARY PARTS OF CIVIL ENGINEERING;

WITH DESCRIPTIONS OF THE BEST INSTRUMENTS EMPLOYED IN SURVEYING AND LEVELLING, THEIR ADJUSTMENTS AND METHODS OF USING IN THE FIELD.

Illustrated by numerous Plates and Diagrams.

BY

PETER BRUFF,
SURVEYOR, &c.

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PREFACE.

The idea of writing this Treatise suggested itself to me a considerable time since, from knowing the repeated inquiries that had been made for such a book; and after perusing, I believe, every work that has been published on the subject, I was fully convinced of the necessity of such a work, adapted to the present improved practice. Of the works on Surveying, I may say, they are all elementary, and of ante-date, no treatise, that I am aware of, having been published since the fine mathematical instruments at present in use have been considered a necessary adjunct to the successful prosecution of land surveying. Of the treatises published on levelling, there is only one of recent date, by Mr. Sims, that can be referred to, and I consider that does not supply the wants of persons seeking information on the subject.

The few rules and suggestions that I have thrown in at the end of the volume, I hope will be found of service.

Many facts and suggestions that I wished to embody in these pages, I have been compelled to omit, from not having time to put them in an intelligible shape. I have transcribed but little from other works, although, where the subjects are the same, there is necessarily a similarity.

In the Theory of Levelling, I have extracted portions from Playfair's Philosophy, and Hutton and Barlow's Philosophical Dictionaries; the article on Refraction, from Robson's Marine Surveying; some facts connected with the tides, from the Encyclopædia Britannica; a portion of Subterranean Surveying, from Fenning's work on that subject. I have also carefully looked over Mr. Sims's work on Levelling, and his Treatise on Mathematical Instruments, to which the reader, requiring more detailed accounts of, is referred.

The method of laying out Curves is adapted from the Railway Magazine, to which publication I feel indebted. I would have added further examples in Surveying, but for want of time, am unable to prepare them for the press.

P. B.

22, *Charlotte Street, Bloomsbury,*
April, 1838.

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PRACTICE OF SURVEYING.

SURVEYING, in a general sense, denotes the art of measuring the angular and linear distances of objects, so as to be able to delineate their several positions on paper, and to ascertain the superficial area, or space between them. It is a branch of applied mathematics, and supposes a good knowledge of arithmetic and geometry. In the erection of extensive buildings; the forming of new roads, or altering of old ones; in the sale or purchase of property; or, in fact, in any alteration of, or change in, landed property, a survey is required.

It is most essential that the survey when made should not only contain the correct area, but also that every part should occupy its proper and true position, otherwise serious evils will result. The importance then of a survey being admitted, it becomes the student's duty to make inquiry for the most accurate method. It is admitted, when a survey is made with the chain only, that numerous lines are measured only for the purpose of fixing points by which to determine the positions of the objects to be delineated. Now by the use of angular instruments these points are determined at once, and far more correctly, without scarcely any other lines being measured than are used in the detail of the work; thus time is saved by the use of the instrument. Many people object to the use of angular instruments in a survey, alleging that far more correct results may be obtained with the chain only, which is a complete delusion—position, not distances, being determined by the instrument (at least in land surveying); and where the angles of a trapezium or triangle, into which all figures should be resolved, are taken with a good instrument, and the sides of these figures accurately measured—we say, when the work thus taken is laid down on paper, if the measured distances of the lines coincide with those protracted on paper, the position of such lines must be correct, consequently such points, as it was the object to delineate by means of the lines, must also occupy their true position. It will be our object, in the following pages, to direct the student how to accomplish his object in the best manner, under a variety of circumstances.

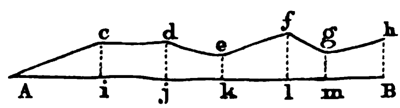
GENERAL OBSERVATIONS,

WITH DIRECTIONS TO BE OBSERVED ON COMMENCING A SURVEY.

SURVEYING may be performed in various ways with the chain only, or by means of angular instruments with the chain. In the first place, it should be observed, that the base or principal line of a survey, from which all the other lines diverge, should, if practicable, be carried through the greatest extent of property to be surveyed, so as to intersect the principal or most intricate parts of the work; it is also as well to carry your base line near midway through the property, so as to leave nearly the same quantity of work on the one side the base, as on the other. Then your tye-lines in filling in, crossing your base, and tying into the opposite line, will be a satisfactory test of the accuracy of the work, and will ensure the exact positions of the different objects to be delineated in a survey. Chain surveying is much more limited in its capabilities than surveying with an instrument, and certainly not so correct. In surveying with a chain you are, in every case, limited to one figure, a triangle; and the correctness of the survey, and relative position of all objects to be delineated, entirely depend on the extreme accuracy with which the sides of this figure are respectively measured. Precipitous or enclosed ground with strong fences, render it almost impossible to measure the distances with that degree of accuracy requisite; an error of only a few links in the side of a triangle, only determined by admeasurement, is not confined to that side on which the error is made, but extends to the whole figure: altering the position of every object enclosed within it. Not so, if the positions of these sides are determined with a theodolite, or other angular instrument; for, in any case, if the angles are correctly taken, the sides will be placed in their true position, and the admeasurement with the chain of these sides will determine the correctness of the angles, so that the angles and measurement are mutually checks on each other. Too much care cannot be bestowed on the measurement of a base line, for on the correctness of a fundamental base, every part of the survey depends—whether trigonometrical, or plain surveying with the theodolite and chain, or chain only. Another important point to be attended to is, always previous to commencing a survey to accurately measure your chain. To do this, tighten it on a level piece of ground, and with a ten-feet rod (correctly marked off from a two-feet carpenter's rule, or a plotting scale) carefully measure the chain, and, if in error, you must remove a few rings, or shorten some of the links, observing that you correct the error equally on each side the mark denoting 50 links; if the error be considerable, you must distribute it equally, as near as possible, over the ten divisions of the chain; but if only half a link or so, you may shorten the first link from each end of the chain; the centre division will then always be in the right place, and the other divisions will be so triflingly in error, as not to be worthy of notice. It is not the error existing in one chain's length that is so dangerous, but that error occasionally increasing; as for instance, suppose a chain to have expanded only one inch in its length, and you measure a base line of three miles through a parish or estate, the error in the length would be 20 feet, which would make a great diminution in the quantity of land surveyed. We cannot impress too earnestly on the surveyor's mind the absolute necessity of attending to this last instruction, and never, in any instance, to commence a survey without previously testing his chain, as it is generally, we may almost say universally, neglected; surveyors being satisfied that their chains were correct when they purchased them (but which is not always the case), and that they will continue so, or perhaps trying them two or three times in a year. To show the necessity of attending to this point, in a recent survey in which the Author was engaged, there was also employed an eminent local surveyor: at the conclusion of the survey, our separate portions would not connect, indeed it was very apparent on inspecting the plans that a serious error existed; our chains were immediately measured, when the local surveyor's was found to be nearly 2 feet longer than it ought to have been, immediately showing where the error existed. When the surveyor is quite satisfied that his chain is correct, he should set off its length upon some convenient spot, and mark the extremes in such a manner as to preserve the means of daily comparing it while in use; thus the slightest elongation would be immediately detected, and easily rectified While speaking of chains, it would not here be amiss to recommend a 100-feet chain, or a 132-feet chain, divided into double links, in every case, in preference to Gunter's chain of 66 feet; as you can measure a line with much greater accuracy with a long chain than a short one, for the same reason that you can measure a line on paper more correct with a long scale than a short one; viz., that you have not so many lengths to measure off, each repetition producing an error, which, although small in itself, when multiplied by a large number produces a very sensible quantity; which any one might prove by measuring off a few lengths of a short scale on paper, and afterwards applying thereto a much longer one Also in measuring over a wall or thick hedge, through which you cannot pass the chain, the angle formed with the long chain would be more obtuse, and approach nearer to a horizontal line than if a short one was used; as in the latter case you would lose several links, the angle formed with the horizon being greater than the former, and if you allow for it by bringing the chain a few links forward it would be at random, and consequently very uncertain. Rapidity in plotting is also another advantage attached to the use of the foot or double-link chain, and a great saving of time in reading off the distances in the field, although, for computing the quantities, you must still come back to the chain scale of 66 feet for convenience in reducing to acres. Though it is generally held bad to plot with one scale, and calculate the contents with another, yet we are convinced that much more accurate results would be arrived at if adopted; always observing that the scales you plot and calculate with are both of the same material, either box or ivory, although we would recommend box, as being less liable to be acted on by changes in the atmosphere.—(See article on the Chain.) A custom is also very general, among some country surveyors, of only using nine pins or arrows instead of ten, making a huge mark or hole in the ground in place of the tenth; a custom which cannot be too much condemned, as being incompatible with correct admeasurement; as, in the next chain forward, in place of holding to a pin, you hold over a large hole, generally a link or two broad, which on a line of any great extent would introduce large errors. All lines measured over steep ground must be reduced to the horizontal measurement, otherwise the work will not plot, and there will appear a greater quantity of land than there really is: this must always be attended to. Generally where hedge and ditch divides property, the brow of the ditch is the boundary; hence the advantage of the surveyor passing his lines along the ditch side of fences. But the brow of the ditch is not always the boundary, it being in some districts the roots of the quicks or the foot of the banks; therefore the necessity of making inquiries as to local custom: the width taken for a ditch that is partly filled, is generally about 6 links, and for the bank about 9. In some places, 3 feet from the roots of the quicks are allowed for the breadth of the ditch, in some 4, in some 5, and in some 6; but 6 links are commonly allowed for ditches between neighbouring estates, and 7 links for ditches adjoining roads, commons, &c. Where a boarded or post and rail fence comes in the surveyor's way, coupled with hedge and ditch, he will often be at a loss to know the precise boundary of the property—when this is the case, observe from which side the nails are driven (it being generally understood that nails are driven homewards;) if on the ditch side the brow of it will be the boundary, if on the other side the fence itself: where a fence changes from one field to another, correctly mark it on the plan—the breadth of the hedge and ditch must be shown, which, as we before observed, is generally taken at 15 links. When plotting a plan the surveyor should be careful always to have the North upwards, and the writing from West to East.

On the Method of Taking Offsets.

A *c d e f g h* being a brook or crooked hedge,

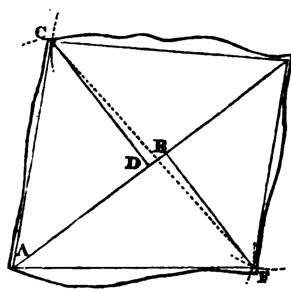


From A measure in a straight direction along the side of it to B; and in measuring along the line A B observe when you are opposite any bends or corners of the hedge, as at *i j k, &c.*, and from thence measure the perpendicular offsets, *i c, j d, &c.*, with a tape or offset staff. When these offsets are marked off from the distances on the line A B, a line drawn through their extremities will represent the crooked hedge A *c d, &c.*

To Survey a single Field with the Chain only.

Having carefully read the general observations, and the method of taking offsets, directions will now be given for surveying a single field with the chain alone. As before observed, in a chain survey you are confined to one figure, a triangle; and the correctness of every part depends on the extreme accuracy with which its relative parts are measured, as well as the judgment displayed in the arranging or laying out the sides of this figure on the ground, which should always, as near as possible, be an equilateral triangle; for if the angle at the apex be either very obtuse or acute the most trivial error in the admeasurement of any one of the sides will materially alter the figure, and consequently the area. As it is better to proceed gradually, we will commence with a single field, as the same system is pursued throughout, whether it be a small enclosure or a large estate. The first operation is in the arranging the ground to be surveyed, either into one or more triangles: that is to say, you station yourself at one corner of the field, and having erected a conspicuous mark at your starting point, look to the opposite corner, and if no natural mark, as a tree, house, or any other object, exist in the line you intend measuring, you must erect one; having done which, commence chaining from the first mark in the direction of the second, always observing that you measure in a perfectly straight line. Leave marks on this diagonal or principal line for the purpose of measuring tye or check lines to the apex of the triangles, to ensure the accurate measurement of the sides. Note in your field-book at what distance from your station or starting point you put down these marks, or false stations as they are termed. When you arrive at the opposite corner of the field, put down another mark, and from this station commence measuring a line by the side of one of the fences, without regard to the angle it makes with the preceding line, taking offsets to all the bends in the hedge as you proceed; put down a mark at the end of this line, as before, and commence measuring a new one to the station first started from, also taking offsets as you go along.

Now measure the tye line from the apex of the triangle or junction of the side lines to one of the previous marks left on the diagonal, which will ensure the accurate measurement of the sides. The same operation will be repeated on the other side of the diagonal, when the survey of the field will be complete.

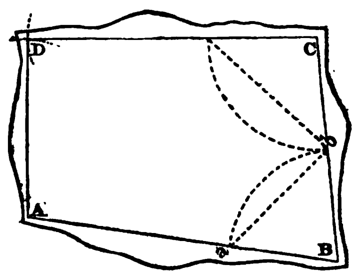


The preceding sketch shows at once the method of procedure in surveying a single field: A B being the diagonal or base line, E D the false stations, left when measuring the diagonal; B C one side of the triangle, commenced from the termination of the diagonal, and C A the remaining side of triangle, which finishes the figure; having arrived at the point from whence we set out. We have now to measure the line C D, which verifies the measurement of the triangle A C B. The same method of procedure is adopted on the other side of the line A B, respectively measuring the sides B F and F A, and the tye-line F E; or one false station may be left on the diagonal, and the continuous dotted line F C measured. The next operation is to lay down these lines on paper; to do which, fix on a scale to which it is intended plotting the field, as one, two, or three chains to an inch, according to circumstances. This determined on, draw the line A B in any position, and measure off the length with the scale, being careful to mark the position of the false stations E and D; then take the length B C with a pair of compasses (beam compasses are the best) and describe an arc of a circle from B as a centre; also take the length A C in the same manner, and describe an arc from A as a centre: the intersection of these arcs will fix the relative positions of the lines A C and B C, through which point draw them from A and B. The same method of procedure would be observed on the other side of the diagonal in laying down the lines A F and B F. Then apply the scale to D, and observe what it measures to the point C; also from E to F. If these distances are the same as measured in the field, it shows that the measurements were correctly taken; if not, it shows than an error must have been committed, either in laying off the lines on the plot, or measuring them in the field; in which case it must be gone over again until it proves satisfactory.

To Survey the same Field, without a Diagonal, by means of Chain Angles.

This method is not at all advisable, although practised to a considerable extent; there is a little time saved, but the chances of error are considerably multiplied. Commence, as previously directed, at one corner of the field; but instead of measuring to the opposite corner, go down the longest side, and within 200 links, or some convenient number, of the end of the line leave a mark. Now commence a new line, as before observed, without regard to the angle it makes with the preceding; and at the same distance on the new line from the station or point at the end of the last line leave a similar mark. Now measure the distance between these two marks, noting exactly the measurement, even to half a link; or continue the line to the end of the fence, and measure it afterwards. The same method may be pursued at the other angles of the field, although not absolutely necessary.

The following diagram will illustrate the preceding method of surveying a field and the manner of plotting it:—Commence at the angle A, and measure down one side of the fence towards B, and at 200 links, or some convenient number, before arriving at B, leave a mark, *a*; when arrived at B commence a new line, B C, and at the exact distance from B, as you had previously left the mark *a*, put down the mark *b*, and accurately measure the line *a b*. Then continue the line to C, where it



would be advisable to pursue the same method, although it is not absolutely necessary beyond being a check on the work.

We think we have now sufficiently shown the method pursued in surveying an enclosure without a diagonal; and will proceed to plot these lines. First: draw the line A B in any position, and with the scale to which it is intended to plot the enclosure, accurately mark off the distance from A to B: then take the distance from B to *a*, or B to *b*, which is the same, with a pair of compasses, from a much larger scale, the larger the better, and from B, as a centre, describe the arc *a b*; then with the compasses take the distance *a b*, and put one foot in *a*, (observing also to take this distance from the large scale) and with the other make a fine puncture in *b*, or describe an arc cutting that point, then with a fine pointed pencil draw in the line B C, passing through the point *b*. Mark off the distance

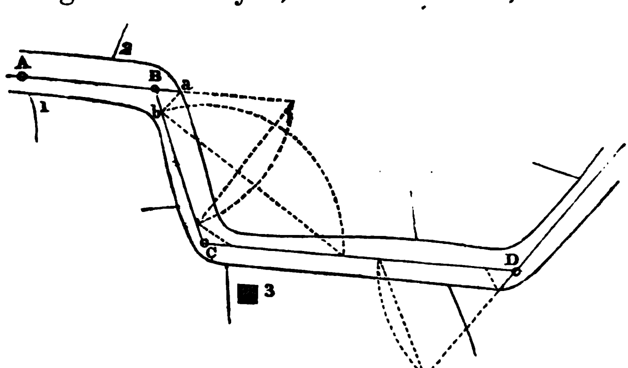
B C from the same scale A B was marked from; then take the distance C D with a pair of compasses, and from C, as a centre, describe an arc, passing through D; also take the distance A D, and describe another arc, cutting the former one in the point D; then, with a fine pointed pencil, draw the lines C D and A D to the point of intersection: the figure will then be complete, or you may take another chain angle at C, or any one of the three remaining angles, similar to the one at B; which would be advisable; for the following reason:—In measuring the diagonal *a b* at the angle B, an error may have been committed in reading the chain; if so, you have no means of detecting it: but if the chain angle is also measured at C you will have a check on the work, as the points D and A being fixed by the chain angles the measured distance D A will not at all come in if an error has been committed, but will either fall short or beyond those points.

The Method of surveying a Field with a Theodolite or Sextant.

Commence on the longest side of the field, and measure quite round it, as in the preceding example, taking offsets at all bends in the fence as before. In the diagram (see last example) commence at A, and measure to B, leaving a mark at the point A, whence you started. When arrived at B, with the instrument look along the line B A, and also to a mark at C; read off on the instrument the angle formed by the line B C with the line B A, and carefully note it in your field-book, measure the line B C, leaving a mark at B. When arrived at C, observe the angle formed by the line C D with C B; measure C D, and when arrived at D observe the angle formed by D A with D C. This will finish the figure: and when the last angle C D A is protracted it will pass through the point A, whence you started, and the measurement of the line D A will be the same on the paper as measured in the field, if the angles and measurements have been correctly taken. For the method of observing with the theodolite and sextant, and plotting the lines, see the directions given under those heads.

To Survey a Road with the Chain only.

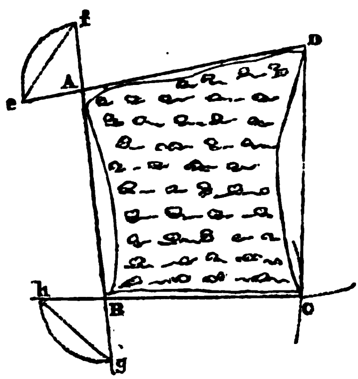
Suppose A B C D to be a piece of road requiring to be surveyed, commence at A, and if no



natural mark exists in the line A B, set up one, observing to get the longest possible sight along the line of road, and taking offsets to all bends in the fences on each side; likewise to all houses and buildings, and note where a fence runs up from the road, as at 1, 2, 3, and so on. Before arriving at B set down a mark, as at C, otherwise continue the line 50 or 100 links, as may be convenient, beyond B to *a*; then commence a new line from B towards C, and at *b*, the exact distance from B as you had previously set down *a*, leave another mark, and accurately measure the distance, *a b*; then continue the line towards C, pursuing the same method at C and each subsequent bend in the road. In plotting the road the same method would be pursued as directed for plotting a field surveyed without a diagonal. The above method would not have much pretensions to accuracy; the angles A B C, B C D, &c., should be determined with a theodolite, or sextant.

To Survey a Coppice of Wood with the Chain only.

Let A, B, C, D, represent a coppice of wood, very much overrun with brushwood, so that it cannot be measured through. In that case take an angle with the chain by measuring 100 links from A to *e*, keeping in a line with A D, and put in a mark at *e*; then measure 100 links from A to *f*, in a line with A B, and measure the distance from *f* to *e*; then

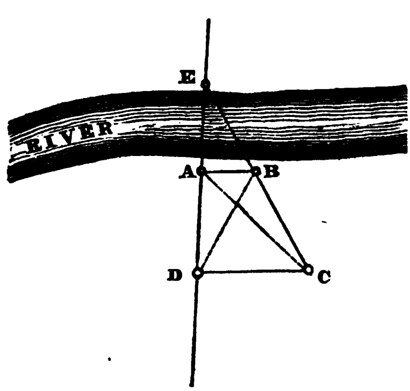


measure, on the outside of the wood, from A to B, and continue the line beyond B to *g*, which is 100 links: also measure out 100 links to *h*, in the line B C, and measure *h g*. Now measure B C, C D, and D A.

To plot the work draw a line at pleasure, to represent the line *e* A D, then put one foot of the compasses in A, and sweep an arch from *e* to *f*, after having taken off 100 links from a large scale. Then take off the distance, *e f*, from the same large scale, put one foot of the compasses in *e*, and bisect the line at *f*; then lay a straight edge on the point of intersection at *f* and the angle of the wood at A, and draw the line A B, and lay off the distance A B, with any scale you like to plot your work with, which may be much smaller than the scale used for laying down the angle. Then take the distance from A to D, which lay off upon the line from A to D by the same scale you used from A to B. If the angle is taken at B, which should be done, the same process is repeated in laying off the angle as at A; if not, take the distance B C, put one foot of the compasses in B, and describe an arch at C, then take the distance from D to C, put one foot of the compasses in D and bisect the arc at C, which will give the exact shape of the wood. Of course the necessary offsets must be taken, as each line is measured. By taking the angle at B a check is obtained on the work, as it fixes the point C, and if that point is laid down in any other position than the right one, the line C D will not come in, but will be too short or too long, thereby proving that an error has been committed.

To take any Inaccessible Distance with the Chain, as the Width of a River, &c.

Suppose in the annexed sketch you brought your survey up to the river, the width of which it



was necessary for you to know:—let D A be your base, or some line well connected with your survey, bring it down to the river edge at A, at which leave a mark, also set up a mark in a line with D A at E, then measure out any distance, as A B, at which set up another mark; then retire back to C, and set up a mark in a line with B and the object on the opposite side of the river, at E: measure B C, and also C D; the distance, D A, you had previously obtained. If you have set out the line D C parallel with A B you may easily calculate the distance A E, in the following manner:—say, as the difference between A B and D C is to D A, so is A B to A E the distance required.

If you wish to lay these lines on paper so as to show the method pursued in crossing the river, it will be necessary to measure either of the diagonals A C or D B, which will divide the figure into two triangles; plot these triangles by intersection, as before directed, then produce D A and C B, until they intersect at E, apply your scale to A E, and it will give you the width of the river.

To Measure over a Steep Hill with the Chain, so as to reduce it to Horizontal Measurement.

The method adopted in measuring over a hill to reduce the line to horizontal measurement, is by taking short lengths of the chain. If the hill is not very steep, take half a chain's length, or if very steep, take 25 links, or less. The foremost chainman in ascending a hill holds the chain quite to the ground, while the hindmost chainman takes 50 links, or as much as the ground will permit him, and holds it up over the mark, and as near level as he can guess. In descending, the reverse will be the case, the hindmost chainman holding to the ground, and the forward man elevating the chain until he thinks it level, and then dropping his pin.

Many surveyors who adopt this method in crossing hilly ground have a plumb line, which the man elevating the chain holds in his hand. By this means you can tell exactly, when ascending, if the chain is over your mark, and, in descending, where to put in a pin. This method may be successfully practised where the ground is at a moderate inclination, but when very steep the vertical angles should be taken with a theodolite, and the requisite allowance made.—(See description of the Theodolite.)

Example in Surveying, with different Methods of Keeping the Field-book.

To survey the annexed three fields the same method should be observed, whether an instrument was used or the chain only. You will commence at A (see Plate 1), where you must set up a mark, that being the extreme boundary, and measure a straight line to some object at B, which is the longest line that could be obtained through the property, leaving marks, which are termed false stations, at *a* and *b*. You must then go off with a line to D, leaving a false station at *c*. When you arrive at about D you will be able to see the mark you first set up at A, to which you must measure a line from the termination of the last at D, leaving another false station at *d*. You will then have enclosed all the property on one side of your base. You must now commence again from A, and measure a line to some object at C. When you come to about *e* you must put down the mark *e* in a line with the two false stations at *b* and *c*; when you arrive at C you will be able to see your mark at B, up to which you must measure. This will finish your great figure, enclosing all the property. You have now to fill in the detail, to do which measure *e*, *b*, *c*, which is a straight line, cutting the base at *b*; when you arrive at *f*, which is in a line with the two false stations at *a* and *d*, you must put down a mark, *f*; you must also note exactly the distance from *e* to *b*, and continue on the chainage to *c*. Then measure *f*, *a*, *d*, correctly noting the chainage when you arrive at each false station. These internal lines, it is evident, will form a check on the accuracy of the triangles A B D, and A C B.

Of the field-books we need only to refer to them, and leave the reader to make his choice. The field-sketch we prefer, as being less liable to error, and all the minutiæ of the survey being sketched in at the time, so as greatly to assist the memory in plotting. It may be thought by many persons, that the sketch field-book is only applicable to the survey of a few fields, but with a little practice it may be used in surveys of any extent. In the common method of keeping a field-book, it is absolutely necessary to plot the work as it proceeds, *which is advisable in all cases,* but in the sketch field-book it may remain for months or years, and then be plotted with as much facility as at first. The Author has a sketch field-book of an intricate district of some thousand acres, comprehending one of the suburban villages, which was not plotted for some months after being surveyed, but was then done with the greatest ease and expedition.

If an instrument had been used in the above survey, the angles A B D, B D A, would have been taken; also D A C, or B A C, and A C B. The angles formed by the internal lines need not be taken, as their positions would be correctly determined by the outer lines. But without an instrument, if an error of 20 or 30 links was committed in measuring the line A C it would not be detected, the point C being determined by intersection, except by measuring a line from the apex of the triangle at C to some part of the base, and the same on the other side; or a line should be measured from C to D, (see Parish Surveying) which would occupy considerable more time than taking the requisite angles, neither would it be so correct. The same liability to error and uncertainty of detection would exist in the measurement of the other lines: but where an instrument is used to determine the position of the several lines, and every line measured and tied to the base, it is impossible but the whole must be correct.

EXAMPLE IN RAILWAY SURVEYING,

Showing in what manner the Survey for the Railway was performed, and an Explanation of the Field-book.

The base-line A B C was first carefully measured, of which the portion, A B, is only given in the field-book. At the commencement of the base, at station A, was set up a flag, a natural mark being visible at C, in a line with the intended base. Before arriving at the first fence a false station was put down *a*, and the exact chainage (540) was entered in the field-book, and also at the crossing of the fence; farther on another false station *b* (1,330), was put down, the crossing of the fence being noted as before; and in a similar manner were put down the other false stations *c* (2,240), *d* (3,380), *e* (4,080), and, lastly, that at B (4,720).

Many surveyors, after measuring out a certain length of base, as A B, would commence at B, and work back to A, but as that method would perhaps perplex the beginner, it will be better to return to A to commence. The first thing to be done is to take the angle formed by the line A *f* with the base; but you must take care to choose your mark at *f*, so that you can produce or back your line to *g*, so as to form one straight line *g* A *f*, then put down a false station at *g*, from which commence your chainage to *f*, taking the necessary offsets, and accurately noting the distance *g* A, at the crossing of your base; when you arrive at the top of the field you must fix your station at *f* in such a position as to get the most favourable and longest line, by the side of the next fence or fences, as *f*, *h*, *i*, *j*; enter the false station at *f* in your book (580), and continue the line beyond *f*, until it cuts the fence; which it does at 600. Then take the angle formed by the line *f h i j* with the line you have just measured *f a g*, which is 108° 10′, and measure the distance: on arriving at *h* (480), put yourself in the best position for passing a line down the adjoining fence, as *h a l k*, take the angle formed by this line with your object at *j*, which is 96°, measure this line, which cuts your base, at *a*, the exact chainage of which you must notice (it is 240), and proceed on towards *k*; at *l* you must put down a false station, which will presently be of service to form the line *l m n*, to take up the adjoining fences. From *k* you will measure a line to *g*, which will finish the first field. It will be at once seen that there is no occasion to take the angle *h k g*, as the two points, *k* and *g*, being correctly fixed by the former angles and measurement: the measured distance, *k g*, will not at all come in if the slightest error has been committed. Now return to *h*, and continue the line on towards *j*; when you come to *i* (1,220), take another angle *j i m* (83° 50′), cutting the base at *b*, measure this line, noting the chainage at *b* (220), and continue it on to *m* (615); at which leave a mark. Return to *i*, and continue the line on towards *j*, until you can fix your false station, as at *j*, to command the line *j n*, cutting the base at *c*.

Now you may either measure the angle formed by the line *j n*, off the line *j f*, or you may proceed to *c*, and take it off the base,—which would, perhaps, be advisable; then from *c* (2,200 on the base), take the angle A *c j* (79° 40′), extend the line a convenient distance to *o*, so as to command the line *o p q*, and measure from *o* to *n*, noting the chainage at *j* and *c*; when you come to *n* you will find yourself in a line with *m* and *l*, the two stations you had previously left. Measure *n*, *m*, *l*, noting the chainage very exactly at *m* and *l*. Now return to *o*, take the angle *n o q* (83° 18′), and measure the line *o p q*, leaving a mark at *p* (1,135), proceed on to *q* (2,535), and at *q* take the angle *o q s* (88° 15′), measure *q s*, noting the chainage, cutting the base at B: leave a mark at *r* (675), so as to form a line *r e t*, and proceed on to *s* (1,000).

If it had been thought necessary to give the field-book farther than this road, a false station would have been left at *s*, and the work carried on to *x* on the base, the line *s q* being extended to *y*; the angle *s y z* would be taken, and a false station made at *z*; the angle *y z x* would be also taken, and the line *z x* extended to *u*, so as to form a station in the line *u s v*, the angle being taken also at *u*. But to return to *s*; take the angle B *s v* (87° 20′), and measure *s v*; but when you arrive near the end of the line you must fix your false station *v*, so as to range with the others previously put down at *d* and *p*, measure *v p*, and about *w* you may or may not leave a mark; enter the chainage (445), cutting your base at *d*, put down a false station at *t*, in a line with *e r*, and continue it on to *p* (915), which is *close*. You may now return to *e*, and measure a line *e n*, which will cut the line *v p* somewhere about *w*, and continue the line on to *n* (1,815), which is also *close*. Return to *t*, and measure *t e r*, which will finish the survey up to the road. The other part, on to C, would be continued in the same manner; the lines measured in the field being marked on the plan.

When the student becomes conversant with the above method much of the labour would be abridged, as he would run his lines backwards and forwards, in several instances, without walking to a distant point to resume his work. Neither is it *absolutely necessary* that so many angles should be taken, as those at *h*, *i*, and *c*, might have been omitted, the line *f j* being fixed by the angle taken at *f*. But the advantage of taking these angles is very great, as it ensures the accuracy of the work; as, for instance: suppose in fixing the false station at *i*, you made an error of 10 or 20 links in reading the chain, by taking the angle at *i* this would be immediately detected, otherwise the distance *i b*, would appear to plot correctly; for the false station *i*, being moved forward or backward 10 or 20 links, would not make a sensible difference in the length *i b*: this error in the distance *i b*, would therefore not be detected, but on producing it to *m* the error would be great.—(See the Plan.)

Suppose the false station at *i* moved forwards 20 links to the black line, the distance *i b* would appear to be correct, and the line produced through *b* to * would be also assumed as correct, in consequence of the measurement, *i b*, answering to the position of *i* on the plan, on reference to which it will be seen how much the position of *m* would be altered: it is true the line *m l* would correct this, but suppose the error of 20 links to be committed at *h*, the station at *l* would then be as much in error as that at *m*, and the line *m l* would plot correctly as to length; but it would be said the measured distance, *k g*, would ensure the accurate position of *k*, but in the general method of surveying; the distance, *k g*, would be necessary to fix the point *g*, which would consequently be as much out of its proper position as the other stations, therefore *k g* would plot correctly, and the whole survey be twisted out of its proper position.

We do not mean to assert that a person making the above survey without an instrument would lay out his lines in the same manner; therefore the inference drawn of an error committed at *i*, extending back to *g*, may by many persons be set down as erroneous; but, although the same distribution of lines would not be observed, the consequences pointed out would ensue wherever an error was committed, which, if of small amount, it would be almost impossible to detect.

The field-book is a sketch made as the work progressed; the several lines being entered as they were measured, and the offsets in the order they were taken. The same method is observed, as in the common system, by commencing at the bottom and writing upwards.

This survey was made with a sextant—if the angles had been taken with a theodolite, the first thing determined would have been the angle formed by the base line with the magnetic meridian (for the method of doing which see directions for observing with the theodolite) which it is always desirable to ascertain, as your theodolite being set to this reading at any subsequent station on your base will point out its direction; also when arrived at the end of your base, if of any considerable extent, it would be desirable to bisect the back station, and note the bearing, the difference would be exactly 180° if you have measured in a straight line; it also often happens when surveying near a town, that you are compelled to take up a long line of road running out from your survey with many bends in it, your bearing will here be of service, as probably you will not be able to connect the extremity of this road with any other part of your survey than that you started from, the position of every part of the road (which is generally of importance) depending on the accuracy of your angles. In this case there are various ways of checking the work, but the most simple and generally practised, where you are pretty certain of the correctness of your angles, is to note the bearing of your last line, and when plotting to lay off this bearing, and with a parallel rule bring it down to the bearing taken on your base, with which it should exactly correspond.

It will also be found of great advantage in measuring a base line to have its bearing, otherwise (except in a very open country) it will be almost impossible to measure it straight, without first ranging it out with poles, as in passing through a plantation or orchard you are pretty certain to lose sight of your marks, you have then nothing but your bearing to satisfy you that you are in the right line.—For further directions in measuring a base, and in general surveying, see observations on parish surveying.

Of Parish Surveying.

Previous to appending any remarks or instruction of our own on parish surveying, we think it right to direct attention to the following extracts on the subject from Captain DAWSON's invaluable Report to the Tithe Commissioners: it is necessary, he observes, to determine the area of the whole parish by some means, which make the correctness of that area independent of the result obtained by summing up the contents of each enclosure, minute errors in many of which would escape observation, if not checked by comparison with the correctly ascertained whole. It is essential, in fact, to arrive at the total area of the parish by direct admeasurement of the space included within its external boundary; and the simplest and cheapest means by which a survey and plan may be made for effecting this object appear to me to be as follows:—

1st. To measure two straight lines through the entire length and breadth of the parish.

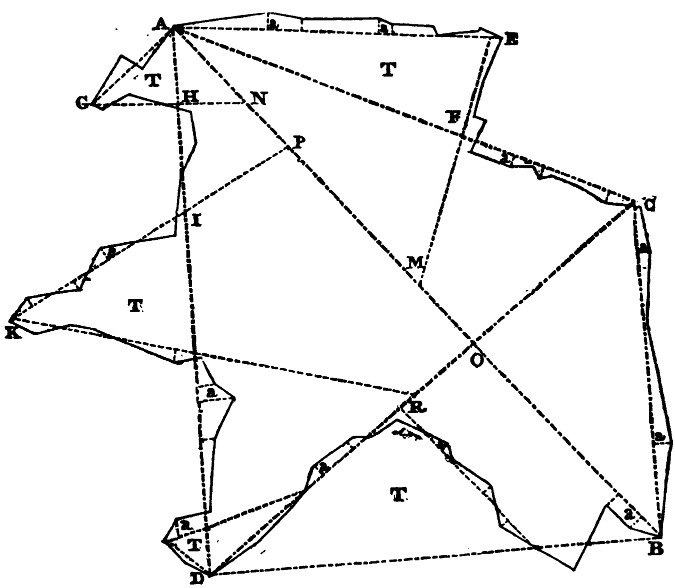
2nd. To connect the ends of these lines by means of other measured lines; and

3rd. From these connecting lines (by measured triangles and offsets) to determine the entire parish boundary.

The true area of the parish may then be obtained by calculation from the measured distances, and by the admeasurement of the included space upon the plan.

Lines of the description herein proposed to be measured are ordinarily used by surveyors in the construction of their plan, but are not always shown on the finished map; I propose to retain them permanently for purposes which will presently appear.

The object and application of these lines will be better seen by reference to the diagram beneath, which is a rough sketch of a parish to be surveyed.



The two main lines which I should recommend to be measured through it are marked A B and C D; A C, C B, B D, D A are the connecting lines. *a a a*, are the offsets, or perpendicular distances of the several angular points of the parish boundary from the measured lines.

Now, if the main lines A B and C D be measured accurately, and their true lengths from the point (O), at which they cross one another, be laid down upon the plan, it will be seen that the connecting lines A C, C B, &c. will form an efficient check on the general direction of the two main lines with reference to one another. A satisfactory check on the *lengths* of the several lines will, by the same means be afforded; for as the points A, C, B, D, are in each case determined by the intersections of three lines, an error in any one of these lines must immediately be discovered.

Thus the true relative position of four extreme points (A, C, B, D), in the parish boundary will be obtained, and such portions of the boundary as fall within the ordinary range of offset-distances from the connecting lines (A C, C B, &c.) will also be determined, and may be laid down in their true positions.

The more remote parts of the parish boundary may be determined by means of the triangles (T, T, T), the sides of which (E F, G H, K I, &c.) being prolonged on the ground to intersect the main lines A B, C D (as they do at M, N, P, &c.), may be laid down correctly in position and direction upon the plan. By this simple process the whole boundary will be determined, and the total area may then be ascertained.

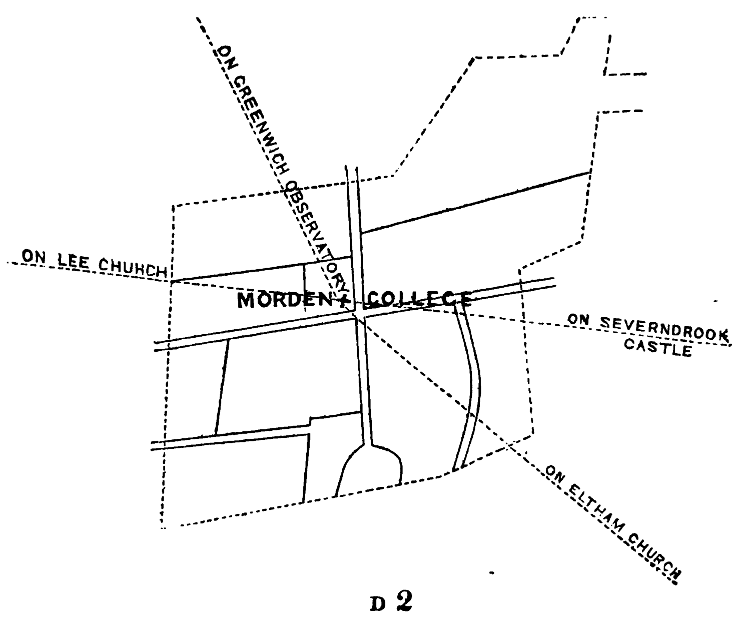
Among the objects to be particularly attended to in practice, is that of reducing the lines, measured over steep slopes in hilly districts, to the horizontal plane.

This demands especial mention, because some inattention to it is not unusual, though the necessity for such reduction is well known to practised surveyors, and all should be alive to the importance of using a theodolite, spirit-level, or other assured means, in the measurement of lines over hilly ground, for determining the exact allowance to be made. Without this reduction of the lines they cannot be laid down in plan upon a flat surface, and distortion of the outline must inevitably result.

Care, of course, must be taken in all cases to measure the lines straight to the points desired; and this will require more particular care in a mountainous, rocky, marshy, wooded, or thickly inhabited country. The expedients in use among practical surveyors will of course be resorted to for overcoming any difficulties which may attend the measurement of these main lines, and the theodolite offers a never failing resource in all cases where a departure from the direct line is inevitable.

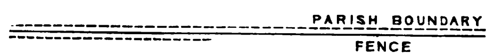
Observations.

The lines which have been described as essential to be surveyed, should, in all cases, be marked upon the plans. They should be drawn in red ink, in order to distinguish them from, and prevent their interfering with the lines of fences, &c.; and the length of each line in links should be marked in red figures upon it. Lines measured in the direction of external objects, should be drawn out to the margin of the plan, and the name of the external object should be written upon the line thus :—



The main lines should be selected, as much as possible, with reference to permanent well-defined objects, such as churches, &c. In other cases it will be desirable that the extremities of the lines (or of some of them at least) should be marked, and preserved on the ground by stones or posts, or by trees, planted there so as to admit of the points being referred to at a future time.

The parish boundary should be shown, in all cases, by a dotted line; and when it passes along the middle of a fence, the dots should be drawn on both sides of the fence, thus:—



When a road forms part of the boundary of a parish, both fences of the road should be shown; and it will be desirable also to mark the abutments of other fences upon the outer fence of the road. The same remark will apply to rivers generally; and in Lincolnshire and other fen districts, to droves and the drains by which they are bounded, &c.

When a parish boundary passes through a field or other enclosure, without being defined by a fence, the whole of such field or enclosure should be shown on the plan, with the parish boundary, marked by a dotted line, passing through it. The area of the included portion only of such field or inclosure will appear in the schedule; but the area of the excluded portion may with propriety be given on the plan, and be marked as belonging to the adjoining parish.

In all cases of fences, the actual boundary line of the adjacent properties should be marked upon the plan, whether it be the central line or the side of a hedge, ditch, wall, bank, &c.; and when the fence belongs entirely to one property or the other, that should be indicated by the proper mark.

The plans are to be drawn to the scale of three chains to one inch, to admit of the correct computation of the contents of the several lands. And the ordinary usage should be observed with regard to placing the north towards the top of the plan; writing the name of the parish, as a title, with that of the county in which it is situated, and adding the name and address of the surveyor, the date of performance, the scale, and the total contents.

The extracts we have made from Captain Dawson's Report are so much to the point, as necessarily greatly to abridge our remarks, which will be confined simply to the guiding and directing persons in the measurement of such lines as are therein recommended. In the first place, then, we will endeavour to point out the best and most correct method of measuring the principal base through the entire length of the parish. Previously to commencing or arranging the work, the surveyor should, if possible, procure an old map of the parish, which, however incorrect it may be, will still serve generally to point out the best parts of the parish through which to pass his lines: but whether this is obtained or not, let him be in no hurry to lay out the work, but look carefully to the consequences resulting from transverse lines running through various parts of the parish—whether their extremities can be easily connected, and if they intersect any particular or important points within, or are on, with any without the parish. This is particularly to be attended to, as it would greatly facilitate the tracing of the boundary at any future time.

We will suppose, then, the surveyor to have decided on the point of commencement and direction of the base, which, if possible, should be on, with some conspicuous permanent mark, without the bounds of the parish, as a church, windmill, house, or such like. At this point set up your theodolite, and ascertain very exactly the angle formed by this line with the magnetic meridian; then take angles to several conspicuous objects around, which would serve hereafter very accurately to determine the point. At this spot erect a pole, very perpendicular, and commence the measurement of the line; but before proceeding further, it cannot be too strongly enforced on the surveyor's mind the absolute necessity of extreme exactness in this part of the operation; for which purpose a much longer chain is recommended than that usually adopted.—(See remarks on the chain.)

At about every 5 or 10 chains, it would be advisable to drive a stake firmly into the ground, with the chainage inscribed thereon in Roman characters: thus, if at every ten chains, call the first ten 1, at twenty it would be 2; or if left at every five chains, at five it would be 1, at ten it would be 2, and so on. The reason of this will be presently apparent.

The roads, rivers, brooks, fences, &c. as they are crossed, should be very carefully noted; but in this stage of the proceedings it would be quite useless putting down false stations at nearly all the fences, as in common surveying. Offsets, if within distance, should be taken to all conspicuous objects. At certain prominent points, as you pass along, set up poles; these will serve to keep you in a direct line, even if you entirely lose your forward object. Your forward chainman must at each chain's length plumb back to those poles you have erected, and by keeping them exactly in a line, you need not fear of departing from your true course.

If you come upon a house, or gentleman's pleasure ground, through which it is impossible to measure a line (but this always should be avoided, if possible:) the means of overcoming the difficulty will be found by referring to a chapter on the subject, in the section devoted to levelling; but the most ready and correct method would be, very carefully to measure an angle with the theodolite, either to the right or left of your line, of exactly 60°, and measure out any length until clear of the obstruction; then take another angle of exactly 60°, and measure the same distance as the last line. This will bring you to the exact spot you would have arrived at, could you have continued your line onward without interruption. You will thus have measured two sides and angles of an equilateral triangle. The remaining angle and side will be the same; that is, the angle will be 60°, and the distance, if it could be measured through the obstruction, would be exactly the same as that of either of the measured sides; or a line forming any angle with the base (but which must be determined) being measured clear of the obstruction, and an angle taken at the extremity so as to cut the base beyond the obstruction, the length of this side and of that passing though the obstruction may be easily calculated by plane trigonometry. This difficulty overcome, and the continuous distance entered in your book we will proceed onward; but the poles you have set up behind are not visible, neither probably is your forward mark. To extricate yourself from this dilemma, measure the supplementary angle of 120° from the last measured side of the equilateral triangle; this will direct you in the precise line; but to verify it, ascertain its bearing, which should be the same as at first: and in this manner you will be able to overcome all similar obstructions.

We will now suppose the surveyor arrived at the extremity of his base, where he must set up his theodolite, and take the angle of one of the side lines, which should not be very oblique, but as near 45° as circumstances will permit, and, as directed for the base, should, if possible, be in a line with some natural mark. To measure this angle, which is most important, with the requisite degree of accuracy, it should be repeated several times, and a mean taken as the correct angle. Set up a pole at the extremity of the base, and measure this line in a similar manner as directed for the base, putting down stakes at intervals. When arrived at the boundary of the parish, or so far as may be desirable, set up the theodolite and measure an angle from the last line to some object on the opposite side of the parish, transversely, to your base, and another angle to the first station at the commencement of the base line: set up a pole at the exact spot from whence the angles were taken, and measure the transverse line, which can be measured in a perfectly straight line, by adopting the same means as already directed. When this line is measured up to the crossing of the principal base, stop, and, from one of the stakes previously left, measure up to the exact spot at which you cross, and enter the two distances in the field-book. Continue the measurement of the transverse base (driving in stakes at regular intervals as before), to the extremity of the parish, or so far beyond it, as by tye-lines, measured to the extremities of the principal base, the entire parish can be circumscribed; or leaving out such small portions only, as may be determined by small triangles from these principal lines, similar to those marked T, T, T, in the diagram.

In throwing out triangles to enclose any part of the parish that may be without these side lines, if an instrument be used, there will be no occasion to extend them back to the base, without the figure should be very large, or the internal lines can be used for other purposes, than merely to verify the position of the figure; but where a chain only is used, it is indispensable to the correct fixing of the figure that those lines should be so extended to one of the bases. From the extremity of the transverse base very accurately observe the angles of the tye-lines to the extremities of the principal base, and measure these tye-lines in the same accurate manner as the bases, leaving stakes at intervals, and taking offsets to the parish boundary and conspicuous objects wherever within distance. When these angles and tye-lines are measured and protracted, there will be four principal stations in the parish very accurately determined; and by these stations being correctly fixed, each stake on the lines connecting the stations, may be considered as a correctly determined station, and used as such.

It would be advisable, before filling in any portion of the work, to get the boundary of the parish, and all the work laying outside the lines; but if not all the boundary, at least the part on that side from whence it is intended to commence filling in. Internal lines may now be used wherever it is thought necessary, the surveyor confining himself to one portion of the survey only, and entirely filling it up before any other part is commenced; his work will then never get confused. With regard to the direction of such lines as it may be necessary to measure within the principal ones, circumstances must alone direct; but lines may be measured in any direction within this boundary, without regard to poles or false stations that may have been erected during the measurement of the base or tye-lines; for, having stakes at regular intervals of 5 or 10 chains, the distance from any one of them to the point at which an internal line crosses can be measured, and the point determined as correctly as if that spot had been fixed on for a station, when measuring these principal lines; and thus can lines be measured in any direction, always observing that from one point to another must be perfectly straight. The angles of the first few internal lines should be very carefully taken, which will fix their position without regard to their measurements; and on the scale being applied thereto, the distance at which any one of them bisects either of the principal lines will be the same as measured in the field, and the point bisected will be at the same chainage as determined by reference to one of the stakes. If on protraction of the angle it should not pass exactly through the point as determined by measurement, it should be made to do so; more dependence having to be placed on the distances than the angle in this case; but by taking the angle, any error committed in putting down or measuring from any one of the stakes will be immediately detected: points thus determined must be correct.

If the surveyor is expert in the use of the sextant, it would be very desirable to have the angles taken of all the lines, except where well tied; but where only determined by their extremities, the angle should in every case be taken. Particular care is necessary in reducing lines measured over steep ground to the horizontal plane; for the method of doing which see description and use of theodolite, also the method of correction with the chain only. The surveyor is advised to lay down his work as he proceeds, if done every day it would be best; he will then, in the event of committing an error be able immediately to rectify it. The sextant may be used with advantage in filling in, but on no account should any other instrument than the sextant and theodolite be employed.

With regard to computing the aggregate quantity of land in the parish, the principal measured lines, as suggested by Captain Dawson, may be used for that purpose, equalizing and arranging into triangles what may be without; and for the separate enclosures within they may be equalized and arranged in a similar manner. But it would appear to us the most correct method to form parallelograms, or squares, as usually done in large surveys, of about 2 chains, by which the quantities in each enclosure would be very correctly ascertained; and for the aggregate, every fifth or tenth parallelogram might be distinguished by a thicker line; the aggregate could then be easily calculated, there being so many parallelograms of 10 or 20 chains square, or as much larger as pleased; the broken parts of the parallelograms would be calculated as directed in another part of this volume. By this method the contents of all the enclosures added together, and the computed whole would be found (if carefully done) to be so nearly the same, that the difference would be beneath notice.

The contents of the whole, computed by the measured lines, might be used as a check on the preceding method. The lines forming the parallelograms should be permanent, either in faint red or blue; but probably blue would be the best, so as to be distinguished from the measured lines, which Captain Dawson desires to have retained. All the entire squares must be numbered consecutively, and the broken figures (as where a fence crosses), calculated separately; and it will be evident that, in this separate calculation, the ascertained contents must be correct; for, having the contents of the whole square, its parts added together must of course be the same.

On Subterranean Surveying, with Directions for Procedure in Surveying Coal Pits, Mines, &c.

The instrument usually employed in all subterranean surveys is the circumferenter, or a modified instrument, which is half circumferenter, half theodolite, having the large compass of the former, with the limb and vernier of the latter; by which means the bearing can be obtained with much greater accuracy than with the common circumferenter. The method of procedure is to plant your instrument where the survey is intended to commence, and take the bearing to a lighted candle placed at as great a distance in the required direction as can be seen; the distance must then be measured; to do which, remove the instrument, and let a person stand on the exact spot where it stood, holding in his hand one end of the chain, while another person takes the other end with a lighted candle in the same hand, being directed by the former until that hand which holds the candle and the chain is in a direct line with the light whose bearing was taken; there mark the first chain, to which mark the hindmost man comes, the other advancing another chain forward as before; this is repeated until the distance of the light to which the bearing was taken is determined. The instrument is now fixed where the light stood as an object, or at the termination of the preceding bearing and distance, and a second bearing taken, and the distance measured as before: this is repeated until the whole is completed.

As surveys of pits or mines are generally made for the purpose of ascertaining if the workings extend into adjoining property, or for sinking shafts, either for ventilation, or convenience for raising the produce—it is essential, in either case, to mark on the surface the extent of the workings, or the exact spot at which the shaft is to be sunk, so as to open on a precise spot in the pit previously determined on; or it is often the case, that you may have to direct the miner as to the bearing and distance from the extremity of some working to another pit: in either case it is essential to trace the survey on the surface, to do which, plant the instrument as near the pit as convenience will allow, so that when the foresight is put in the direction of the first bearing you may, by looking backwards, cut exactly the centre of the pit; if it does not do so, the instrument is not placed in a proper position, which must be obtained by shifting the instrument to the right or left, until it is in the situation beforementioned; after this is found, measure out the distance of the first bearing from the centre of the pit, remove the instrument to the end of the line, and take the various bearings, and measure the distances, the same as below; or, instead of the above manner, choose any spot near the pit, as the point of commencement, and from this point take the first bearing and distance as in the pit. Before the instrument is removed, take the bearing and distance of the centre of the pit; then remove the instrument to the end of the measured distance of the first bearing, and set the instrument to the same bearing as the centre of the pit had; likewise, measure off the same distance as was the centre of the pit, from the spot commenced on; then a line from the centre of the pit to this spot will be the proper bearing and distance.

It will be frequently found necessary, where only particular points are to be determined on the surface, to reduce the intermediate bearings and distances into one bearing and distance; the most easy and practicable method of doing which, is to apply a good protracter to the meridian line, with its centre on the angular point—accurately noting the angle subtended, and measure the distance with the scale by which the survey was plotted; during the time of making the survey, care should be taken not to admit any iron within three or four feet of the instrument, for fear of attracting the needle, although a large mass of iron will attract it at a much greater distance. The tram plates or rails generally laid down in pits do not seem to attract the needle, if elevated from two to three feet above them; but we have ourselves found the needle very sensibly affected by a large clasp-knife in our breast pocket. As these surveys form records which are being continually referred to from time to time, and additions made thereto, it is necessary to lay down the work in such a manner, that additions at any future time can be correctly attached: this can only be done by referring all the angles to the true meridian, as it must be well known to the most common informed that the magnetic meridian has been continually, and is at present varying—the present variation of the needle is about 27° westward of North; the method adopted by practical miners for ascertaining the variation (for it is not the same in all places), is, to erect a pole exactly perpendicular—its shadow at 12 o'clock will be due North and South, or in the direction of the true meridian; besides the above variation of the needle from the true meridian it has a diurnal variation, which has been often observed to amount to one degree and a half, which may account for inaccuracies that have occurred where the greatest care has been observed in the use of the instrument.

A different method of using the circumferenter, from what we have just now described, is sometimes adopted: it is to plant the instrument at alternate angles, and take back and foresights; thus, in place of setting up the instrument at the commencement of the survey, it is done at the extremity of the first line, and its bearing taken, but with the instrument reversed, that is, you apply your eye to the opposite sight vane to that when a forward bearing is taken: it should be noticed in this case, that the angle is read off from the South end of the needle, which angle is easily reversed and laid off, as if taken from the North end—the forward bearings are taken in the usual manner. A back observation is taken thus, S. 10° 30′ West; reversed, it is N. 10° 30′ East; by this method the instrument is set up only half the number of times, as by the former. We would, however, recommend the theodolite in this as in all other kinds of surveying: in the commencement it would be necessary to determine the bearing, but in the remainder of the survey, it may be used in precisely the same manner as already described for common land surveying: the bearing might also be noted at each station, which would be an effectual check on the correctness of the angles.

ON THE PROTRACTING AND PLOTTING OF SURVEYS; THE REDUCING AND COMPUTING OF AREAS, &c.

It is usual with practical surveyors to plot their work daily, which, if possible, should always be done; otherwise, if left alone for a few days, and an error should have been committed in the first day's work, it will be very troublesome to correct, besides a great loss of time: but by plotting daily, any mistake that may have occurred can be easily rectified. There is also another advantage in so doing, which is, that you are enabled to lay down your work with the most scrupulous exactness, every part being fresh in your memory; and in all surveys there are particular parts which can only be laid down on the plan from memory. If it should be inconvenient to plot daily, your lines of construction should certainly be laid down; the method of doing which, where a chain only is used, is pointed out in the commencement of this treatise; and where an instrument is used, and the angles taken from the meridian, directions will be found in the description and use of the circumferenter.

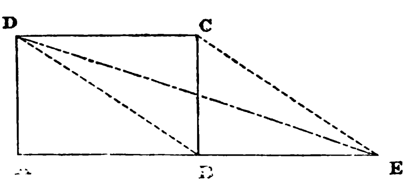
The method of laying down a survey made with a theodolite or sextant, will, therefore, only be given here; to do which, with any degree of accuracy, a circular metallic protracter is indispensable. This instrument, for the general purposes of surveying, should be of about 5 or 6 inches diameter, divided on silver in a similar manner to a theodolite, with two projecting arms carrying verniers, and a third by which the other two are moved round the circle, either with a rack and pinion, or clamp and tangent-screws; but where great accuracy is required, the latter is preferable. The projecting arms carrying the verniers have each a branch, with a fine pricker at its extremity. The inner part of the circle is chamfered off at each quadrant to an edge, and the divisions brought down to it. A small circular space of metal in the centre of the instrument is removed, and a circular disc of glass inserted in its place, on which are drawn lines crossing each other at right angles, and dividing the small circle into four quadrants, the intersection of the lines denoting the centre of the protracter.

When this instrument is used for laying down an angle, it must be so placed on the paper, that its centre exactly coincides with, or covers, the angular point, which may easily be done, as the paper can be seen through the glass centre-piece. The divisions at 360° and 180°, which are brought down on the internal chamfered edge, must be on the line passing through the exact spot over which is the centre of the instrument. When the protracter is thus placed, it is prevented from moving by four small studs, which take sufficient hold of the paper without damaging it; then, by means of the rack and pinion, or clamp and tangent-screws, the vernier may be set to the required angle. A slight downward pressure on the extremities of the branches will make two small punctures in the paper, a line passing through one of them, and the angular point or centre will be the required angle. The use of the second vernier is, that often in setting the instrument to the required angle, the protracter is stirred, and its centre is no longer over the angular point. When such is the case, a line drawn from their punctures will not pass through the centre: the branches will also sometimes get deranged, and the same consequences ensue. To correct this, the branches must be altered by means of two small screws, on which they play, until a line will pass through the three points: this should be attended to before the instrument is used in laying down the angles. When the angles on a survey are taken with a sextant, they are often laid down with a semicircular protracter, without a vernier; which may be also used with advantage when plotting a survey made with a theodolite, except for the principal angles, which must be laid down with the greatest possible accuracy. It should also be an invariable custom with a surveyor to protract all his lines before commencing to plot the fences, &c., as it often happens on closing a day's work, that the last line will not protract, which arises either from some slight error in laying down the previous angles or distances, or in noting them in the field: if this is the case, and the early part of the day's work should be plotted, it is so much waste of time.

ON THE REDUCING OF FIGURES AND EQUALIZING OF BOUNDARIES.

To Reduce a Parallelogram to a Triangle of equal Area.

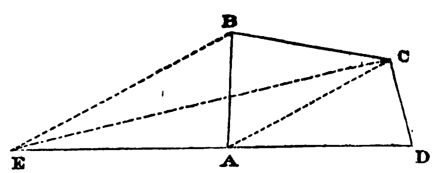
Suppose the parallelogram A B C D, is to be reduced to a triangle, whose area will be the same.



Produce or extend one of the sides, suppose A B, then lay a parallel ruler on the diagonal D B, and move it parallel to C; draw in the line C E, or mark where it cuts the produced line at E; draw in D E, and it is done: it will be the same thing if you prick off the distance A B, on the produced line, which will reach to E.

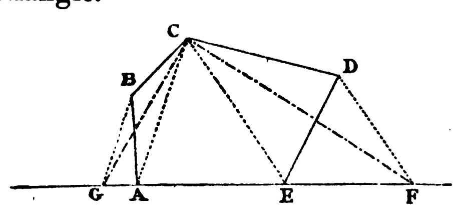
To Reduce a Trapezium to a Triangle of equal area.

Let A B C D be the trapezium. Draw the diagonal A C, and extend the base from A to E; draw B E parallel to A C; from C draw C E, and the triangle E C D will be equal to the trapezium A B C D, which may be proved by scaling the figures.



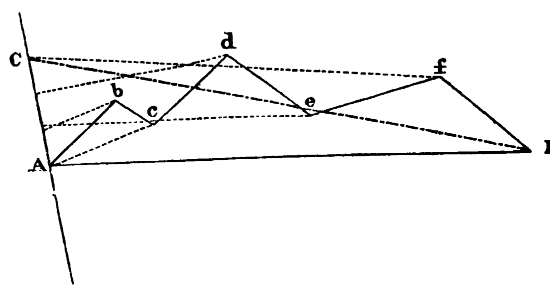
To Reduce a Figure of Five Sides to a Triangle.

Let A B C D E be the given figure; extend the base each way; draw C A, and C E, and B G, and D F, parallel thereto. C F G will be the required triangle.



To Reduce or Equalize an Irregular Side or Boundary to a Mean Line.

Suppose the side of a field to be of the irregular form below. Draw the line A B, and at A



draw a transverse line, which is usually at right angles thereto, except when the equalizing line of the adjoining fence passes through that point. Lay a parallel ruler from A to the *third* point at *c;* slide the ruler up to *b*, and draw in the dotted line to the transverse line, or, without drawing it, mark where it cuts it; from which point lay the ruler to *d*, slide it down to *c*, and draw in the dotted line as before; from the point at which it cuts the transverse line lay the ruler to *e*, and slide it up to *d*, and draw in the dotted line from *d;* lay the ruler from the point of bisection to *f*, and slide it down to *e*, draw in this line, and, from the point of bisection, lay the ruler to B, slide it up to *f*, draw in the dotted line; and from the point of bisection at C, draw the line C B, which will equalize the irregular boundary, as much being cut off as taken in.

This method is rarely adopted in practice; too much time being taken up in the operation, and equally as accurate results being arrived at by a much shorter process, which is to equalize those irregular boundaries by the eye, and by a little practice it may be done with the greatest exactness. A thin piece of transparent horn, or a strip of glass, is recommended for this purpose, by which means you can very exactly judge if you include as much new space as you exclude of the original; or a bow of whalebone, or any elastic substance, strung with horse-hair, will suit as well. But the method generally adopted is to draw an equalizing line, in pencil, with a parallel ruler or straight-edge, which, on being removed, if the line is found to exclude a greater portion of the original than it includes of new space, is rubbed out, and fresh lines drawn, until the eye judges it correct.

ON THE METHOD OF COMPUTING AREAS.

In computing the contents of any piece of land, whether it be one enclosure or a great number, it is done *quite independent of the several lines measured in the field*, except in some cases where the base line and a few others, from their position on the plan, may be used with advantage; otherwise new lines are drawn, dividing each separate enclosure into trapeziums and triangles, the bases and perpendiculars of which are measured on the plan by means of the scale from which it was plotted, and so multiplied, and added together for the total contents. After all the separate quantities are thus computed, and added together in one sum, calculate the whole estate, independent of the fields, by dividing it into large triangles and trapeziums, and add these also together. If this sum be equal to the former, or nearly so, the work may be considered right; but if the sums have any considerable difference, it is wrong, and they must be examined and re-computed until they nearly agree; or the contents may be found in a much more correct manner, by dividing it into a great number of parallelograms, as hereafter explained; it may then be proved by large triangles and trapeziums as above directed.

Of the computing of Areas.

The area of any plain figure is the measure of the space contained within its extremes or bounds. This area, or the content of the plane figure, is estimated by the number of squares that may be contained in it; the side of these squares being an inch, a foot, a yard, a chain, or any other fixed quantity; and hence the area or content is said to be so many square inches, feet, yards, or chains, &c.

Land is estimated in acres, roods, and perches. An acre is equal to 10 square chains, that is, 10 chains in length and 1 chain in breadth: also an acre is divided into four parts, called roods; and a rood into 40 parts, called rods, perches, or poles. The chain generally used, called Gunter's chain, from its inventor, the Rev. Edmund Gunter, is 4 poles, or 22 yards, or 66 feet in length. It consists of 100 equal links, and the length of each link is therefore $\frac{22}{100}$ of a yard, or $\frac{66}{100}$ of a foot, or 7,92 inches.

An acre of land then consists of

1,000	×	100	=	100,000	square	links.
660	×	66	=	43,560	,,	feet.
220	×	22	=	4,840	,,	yards.
40	×	4	=	160	,,	rods.

Lines measured with a chain are set down in links as integers, every chain in length being 100 links; therefore, after the content is found, it will be in square links; then cut off five of the figures on the right hand for decimals, and the rest will be acres. These decimals are then multiplied by 4 for roods, and the decimals of these again by 40 for perches.

To find the Area of any Parallelogram.

Multiply the length by the perpendicular breadth or heighth, and the product will be the area.

To Find the Area of a Triangle.

Multiply the base by the perpendicular height, and half the product will be the area; or multiply the one of these dimensions by half the other.

Example.—Required the area of a triangle, whose base is 1020, and perpendicular height 580 links.

1020	510
580	580
81600	40800
5100	2550
2)591600	2,95800
	4
2,95800	3,83200
4	40
3,83200	33,28000
40	
33,28000	

Equal, 2 acres, 3 roods, 33 rods.

To Find the Area of a Trapezoid

Add together the two parallel sides; then multiply their sum by the perpendicular breadth or distance between them, and half the product will be the area; or multiply one of these dimensions by half the other.

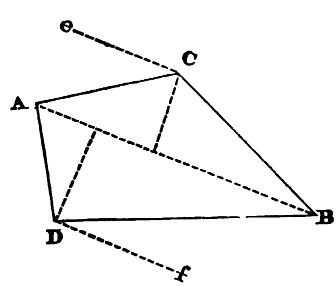
Example.—In a trapezoid the parallel sides are 750 and 1225, and the perpendicular distance between them 1540 links; to find the area

$$\begin{array}{r} 1225 \\ 750 \\ \hline \end{array}$$

1975 × 770 = 1,520,750 square links = 15 acres, 33 rods.

To Find the Area of any Trapezium.

Divide the trapezium into two triangles by a diagonal, add the perpendicular heights together, and multiply by the diagonal; half the product will be the area: or multiply one of these dimensions by half the other



In place of measuring the two perpendiculars separately, and adding them together, and then halving the sum, a practical surveyor would lay a parallel ruler upon the diagonal A B, and move it parallel to the angle C or D, and draw the line C *e* or D *f*, and take off the distance with his compasses from one of the angles to the nearest part of the dotted line, passing through the opposite angle, which will give the same distance as the sum of the two perpendiculars. Apply this extent to a scale double that to which the figure is laid down by, and the trouble of adding and dividing will be saved. This method has also the advantage in point of correctness, for in measuring the perpendicular heights separately there will be small fractional parts that you cannot well estimate.

*To Find the Area of an Irregular Polygon.**

Draw diagonals, dividing the proposed polygon into trapeziums and triangles; find the areas of all these separately, and add them together for the contents of the whole figure.

To Find the Area of any Figure by means of Parallelograms.

This is done by drawing parallel lines, in some faint colour, all over the plan, forming squares of one

* A poylgon is ANY irregular figure having more than four sides, and, consequently, more than four right angles.

or two chains each, which are afterwards numbered consecutively: the contents of all the squares are then easily ascertained, to which is added the contents of the broken squares, which are equalized and calculated as triangles or parallelograms, and the area of each generally inserted on the plan. An example of this method of calculating areas is shown in Plate 5. The squares are of one chain each, consequently the number (79) divided by 10 (the number of square chains in an acre), or, what is the same thing, cut off one figure on the right hand, which is multiplied for roods and perches—that on the left is acres, thus:—

7,9 the number of squares
4
—
3,6
40
—
24,0

	A.	*r.*	*p.*
Contents of squares =	7	3	24
Ditto broken squares =	1	1	31
	9	1	15

It will be perceived on reference to the plan, that in some of the broken squares the contents of an entire square (16 perches) is inserted; but it will be perceived that immediately adjoining these broken squares, in which it is so inserted, that a piece equal to the deficiency is omitted in the calculation. Also where a piece in a broken square is very small, it is carried into the contents of the adjoining one.

DESCRIPTION, USES, AND ADJUSTMENTS OF THE VARIOUS INSTRUMENTS EMPLOYED IN SURVEYING.

Of the Chain and Offset-staff.

THESE are two of the principal instruments employed in surveying. The chain, as before mentioned, is 66 feet, or 100 links, in length, comprising ten divisions of ten links each, which are distinguishable by brass marks, cut into fingers, from one to four, one denoting 10 links, and 4 fingers, 40.—The chain is marked thus from both ends, the centre or 50 links being denoted by a round brass mark and swivel. It is, therefore, immaterial which way you measure with the chain. Four fingers past the round brass mark denotes 60, 3 fingers 70, 2 fingers 80, and 1 finger 90; the end of the chain is 100. It will be found rather perplexing at first reckoning above 50, but a little practice will soon make it familiar: but the student should be very particular when reading the chain at about 60 or 70, as nothing is more common than the mistaking of these marks for 40 or 30.

The offset-staff is a light rod, generally of 10 links in length; the links being marked by notches or brass nails. This is carried by the person following the chain, which should always be the surveyor himself, never trusting to an assistant in this the most particular part of his work. A tape is used generally for measuring buildings, and occasionally for taking offsets; although it is not so handy as the staff, without an extra assistant is employed: a tape of 100 feet in length will be found the most advantageous.

Having, in our general observations at the commencement of the volume, spoken on the advantages of a much longer chain that that of Gunter's, it will only be necessary here to point out the method of setting down the chainage and plotting the work. If a chain of 100 feet in length is used, the chainage would be entered in the field-book, in the same manner as if a common link-chain was used; the only difference would be in the plotting of the work, thus: If a survey made with a 100-feet chain was to be plotted to a scale of 5 chains to an inch, it must be done with a scale divided into 330 to an inch, there being that number of feet contained in 5 chains; that is, there would be 33 divisions, each division representing 10. To plot to a scale of 2½ chains to an inch, there would be the same number of divisions, each division representing 5; but there are some scales into which the 100-feet chain cannot be well subdivided. The most correct and *convenient* chain for use is one double the length of Gunter's, divided into 100 links, each link of which will be double the usual length. This chain may be used in the same manner as Gunter's; that is, the links set down as integers, each link counting but one, although it is actually two: but in plotting, by using a scale double the size of that to which the work is laid down, the results will be the same as if a chain and scale of the usual kind had been used: thus, if the survey is to be laid down to a scale of 4 chains to an inch, by plotting with a two-chain scale the results will be the same as if the common chain had been used, and the work plotted to the proper scale. Also, by having stamped thereon a second division of figures, denoting the proper scale of 4 chains, the work may be plotted, and the contents calculated with the same.

Description of a Circumferenter, and Method of Observing with it.

This instrument is principally used in mines and coal pits, and where a country is thickly overgrown with wood. Each angle is taken with the needle from the meridian, without being at all connected with the preceding portion of the work. A large compass fitted with plain sights, mounted on a ball and socket, and connected with a stand similar to that of a theodolite, forms the instrument.

The internal part of the compass box is graduated very distinctly, sometimes into twice 180°, or four times 90°, as well as quite round the circle to 360°. At zero, or 360°, is fixed a perpendicular sight vane, with a fine wire strained on its opening: opposite to it, over the division 180°, is fixed a similar vane and strained wire; these wires being in the meridian or N. S. line of the compass box. A small orifice is also made in each sight vane, in a line with the strained wire, to which the eye is applied on taking an observation; the object being bisected by the perpendicular wire, thus:—at any station from whence you intend carrying out a line, set up your instrument, and by means of the ball and socket and spirit-bubbles set it level; or, if you have no spirit-bubbles attached to your instrument, notice if the needle plays freely, by which means you may set it up very nearly level; clamp the ball and socket tight, and turn the sights which are fixed to the compass box in the direction of the proposed line, which, when bisected, will give the desired angle, by noting exactly what degree the north point of the needle becomes stationary opposite. As the correctness of this instrument entirely depends on the fine performance of the needle; it will be requisite to have a very sensitive one, and great care must be taken that the instrument is not stirred after bisecting the object, and previous to noting the angle. The needle should always be thrown off its centre, and not allowed to play except when in the act of using it, otherwise the fine point on which it revolves, and its accuracy depends, will soon be destroyed. The student should also notice that in this instrument and, generally, in all modern instruments, the compass is marked contrary to nature; that is, the West is substituted for the East, the North East for the South West, &c.: by thus altering the cardinal points the readings of the needle show the actual direction of the line.

For a further description and method of using this instrument, and plotting the work, see "Subterranean Surveying" and "Prismatic Compass."

Description of the Prismatic Compass, and Method of Observing with it.

This is a very useful little instrument, and is used in the same manner as the circumferenter, that is, all the angles are taken from the magnetic meridian; but, instead of a needle with the graduations in the compass box, it has a graduated floating card attached to the needle, similar to a mariner's compass. This card is usually graduated to 15′ of a degree, but angles cannot be taken with it to less than 30′, or half a degree, which renders it very unfit to be used, except in filling in the detail of a survey, where the principal points have been accurately determined by means of a theodolite, or where great accuracy is not required. The graduations on the floating card commence at the North point, or zero, and are numbered 5°, 10°, &c. round the circle to 360°. Attached to the instrument is a fixed perpendicular sight vane, with a fine thread or hair strained along its opening, opposite to which is the prism. On applying your eye to the prism, and bisecting any object with the thread in the sight vane, the division on the card coinciding with the thread, and reflected to the eye of the observer, will be the angle formed by the object with the meridian; but care should be always taken that the card is quite stationary at the time you note the angle. You should also be careful to hold the instrument in such a position that the card will play freely in its centre, otherwise the results obtained will be liable to great inaccuracy.

The angle formed by one object with another may be easily ascertained with this instrument, first finding the angle formed by each with the meridian, the difference will be the angle required; as for example: suppose you find the bearing of one object to be 20°, of the other 45°, the angle subtended by these two objects will be 25°, which is the less subtracted from the greater; but if the difference be greater than 180° it must be subtracted from 360°, as in the following example: the bearing of one object is found to be 345° of another 30°. The angle subtended in this case will be the difference between 30° and 345° = to 315°, subtracted from 360° = to 45°. But the best method of using this instrument is to keep each angle separate, noting them all in your book from the meridian. You are then less liable to error, and the plotting is performed with great rapidity, by means of a protracter formed on the same sheet of paper that you plot on.

If only filling in the detail of a map, the magnetic meridian will have been previously determined; if not, you must draw one, taking care that you so place it that the paper will take in the greatest extent of survey. A line must then be drawn in a vacant corner of the map parallel with this meridian, and from a metallic protracter mark off the degrees and half degrees, which may be done in a few minutes; number them as 10°, 20°, &c. to 360°, commencing from the North point as on the floating card. Then, to lay off an angle from the meridian, you have only to apply the edge of a parallel ruler to the centre of the circle forming the protracter and the required angle, and slide it parallel to itself to the point from whence it was taken; then draw in the line and mark off the distance: proceed in this way until all the angles taken are laid down on the plan. If the survey is very extensive you may describe two or three of these protracters on different parts of the plan, taking great care that the meridian lines are exactly parallel.

But a much more convenient method of laying down angles taken from the meridian is to make a protracter on a separate sheet of paper or card-board in the manner described above; then cut out the blank paper withinside the circle on which the degrees are marked, and it will prove a most convenient protracter, and may be attached to any part of the map, and the angles laid off as before by means of the parallel rule; or the meridian line being drawn through any point on the plan from whence angles have been taken, can be instantly marked off by laying this paper protracter on the meridian line, observing that the N.S. line on the protracter exactly coincides with that on the plan. The same method of plotting is also observed when the circumferenter is used.

Description, Use, and Adjustment of the Box or Pocket Sextant.

This instrument is the most useful a surveyor can have, and sufficiently accurate for all purposes, except in setting out long lines, or laying out large triangles in a hilly country, where a good theodolite is indispensable; but for filling in the details of a survey, it is unrivalled both for accuracy and expedition. The pocket sextant is usually divided on silver to 140°, although a greater angle than 110° should not be taken with it. A small telescope is sometimes attached to assist the sight, but is very inconvenient, taking up more time to arrange for distinct vision than for taking the angle. There is a small aperture opposite to the half silvered or horizon glass to take plain sights with, in place of the telescope, which is far preferable. The method of observing with the sextant is to place yourself in a line at the exact point you intend carrying out another line, the angle of which with the preceding, you are desirous of knowing. You must take the sextant in your right hand, the case of the instrument forming a handle, and apply your eye to the small aperture, looking through the unsilvered part of the horizon glass to some object or station mark on your line; you will then, wtth your left hand, turn the milled head screw, which carries the silvered glass until it reflects an object on the second line, in the silvered part of the horizon glass; and when the two objects are in exact conjunction (that is, the object viewed direct through the unsilvered part of the horizon glass, and the reflected object appearing as one), the desired angle will be given.

The method of adjusting this instrument is exceedingly easy and correct. You must first observe some well defined object through the unsilvered part of the horizon glass, and turn the milled head screw carrying the silvered glass until the same object is reflected; the observed and reflected object, which in this case are the same, appearing as one; the index or vernier standing at 0° on the limb if the instrument is correct, if not the reading on the limb will show the error of the instrument; or the vernier being set at 0°, the object viewed direct and by reflection should appear as one if the instrument is in adjustment, if not they will overlap and appear unconnected. To remedy this the horizon glass must be altered by means of two screws (one in the upper part of the instrument, over the horizon glass, and the other at the side of it), until the object viewed direct and reflected appear as they really are—one, the vernier standing at 0′ on the limb. A key to fit both screws of the horizon glass is fitted into some spare place in the instrument. The angle is read off with the assistance of a lens, fitted to the instrument with a hinge joint, which allows it to be moved over every part of the limb and vernier.

Description, Uses, and Adjustments of the Theodolite.

Of all angular instruments for surveying this is the best; the improvements it has received from time to time rendering it almost perfect. The theodolites in general use have telescopes mounted in Y *s*, similar to that of the Y level, with the spirit-bubble attached. A semicircular arc for taking vertical angles is also fixed to the Y *s*, the whole moving in a vertical plane, and from the centre of the circle describing this arc are projecting arms resting on standards, which are fixed to the upper plate of the instrument on which the verniers are marked; the plates are called the limb: the chamfered edge of the lower one is divided quite round the circle, as

10°, 20°, &c. to 360°—the intermediates as 5°, 15°, 25°, &c. being represented by longer divisions than the single degrees, and the half degrees, into which the limb is generally divided, by shorter lines than the degrees.

For the purpose of bisecting objects correctly, a slow motion screw is attached to the upper plate, the clamp screw securing it when you have nearly bisected the object; and the slow motion screw moving the vernier through the least possible space, perfecting the bisection. In good instruments, similar clamp and slow motion screws are attached to the lower plate, by which means (as will be presently explained) angles may be repeated any number of times, thereby ensuring the degree of accuracy required. A vernier is fixed to the upper plate, through which the semicircular arc for taking vertical angles passes; two spirit-bubbles are also attached to this plate at right angles to each other, for the purpose of setting the instrument horizontal. A small compass is also attached to the upper plate; the N.S. line of the compass box ranging with the line of sight. The bearings being noted at the different stations serve as a check on the angles. The whole is mounted on parallel plates similar to those of a level.

The principal adjustments requisite to this instrument are the same as those for the Y level (to which the reader is particularly referred); viz., that the line of collimation, or optical axis, of the telescope must coincide with the cylindrical rings on which it turns in the Y *s*, and that the bubble must be parallel to this optical axis. The method of performing these adjustments have been already explained in the account of the Y level. The next adjustment is to make the axis of the horizontal plates truly vertical: to do which, set up the instrument as near level as you can, the telescope lying over two of the parallel plate-screws; then, by means of the clamp and slow-motion screws attached to the vertical arc, bring the bubble connected with the telescope into the centre of the tube; then move the instrument half round, and the telescope will be over the other pair of plate-screws. If the bubble remains in the centre of the tube, it is right, if not, you must correct it, one half by the clamp and slow-motion screw attached to the vertical arc, and the other half by the parallel plate-screws. If the bubble will not now remain in the centre of the tube, while the instrument is turned quite round, it must be repeated until the result is satisfactory, when, if the bubbles on the vernier-plate are correct, they will stand in the centre of their tubes; if not, the screws at either end connecting the bubble-tubes with the vernier-plate must be altered as much as will bring them to the centre of their runs.

The adjustment necessary to the vertical arc may now be attended to. If the vernier stands at zero, when the former adjustments are perfect, it is correct; if not, you must alter the vernier by means of the screws attaching it to the plate until it does, or you may note the error, and allow for it in each vertical angle. But for the purpose of accurately noting this error, it is necessary to take the vertical angle of some conspicuous object with the telescope, reversed in the Y *s;* to do which the instrument must be turned half round, when the telescope will occupy the same position as at first, but the vertical arc will be reversed: the mean of these two readings will be the amount of error; which we should advise the surveyor to correct, in preference to allowing for it at each vertical angle, as being less liable to error.

To Observe with the Theodolite.

The method of observing angles with the theodolite is to set it up exactly over some station, which you can easily do with the assistance of a plummet and line suspended exactly under its centre from a hook attached to the stand; then set it level by means of the parallel plate-screws, clamp the upper and lower plates together, and turn the instrument towards some station mark; clamp the lower plate and make the bisection with the slow-motion screw, observing in every case to bisect the object as near the ground as possible. Then read off the degrees and minutes, also the seconds if necessary, taking the mean of two or three verniers, if you have so many, but two should always be used. The upper plate may now be released (the lower one remaining clamped, care being taken that it has not the least motion), and turned towards another station, clamp it, and bisect with its own slow-motion screw, read the degrees, minutes, and seconds, as before, and their difference will be the desired angle. But for general purposes it will be found much easier and be *less liable to error*, to set the vernier at 360° and clamp it; then turn the instrument bodily round in the direction of the first object, clamp the lower plate, and bisect with its slow-motion screw; then release the upper or vernier-plate (the lower plate remaining clamped), and turn the instrument in the direction of the second station, clamp and bisect as before, and the angle read off will be the desired one. This will be found in practice generally the most preferable method of taking angles, although not so correct as the former, it being almost impossible to set the instrument exactly to 360°: but in extensive operations, and where many angles are taken from one station, the former method is greatly superior. The bearing, which is the angle pointed out by the compass-needle, may be also noted at each *principal* station, which will be a check on the accuracy of the angle; but in the usual description of theodolites, the bearing cannot be read with any degree of accuracy, except by setting the plates and needle at zero, and reading the angle on the limb when the object is bisected, which will be the bearing.

Vertical angles are taken for the purpose of reducing lines measured over steep ground to the horizontal measure. On one side of the vertical arc are engraved the requisite divisions for determining the angle, and on the other the number of links to be deducted from each chain's length, to reduce it to the horizontal measurement; but for the purpose of measuring this angle it is necessary to set up a mark at the exact height of the optical axis of the telescope, at the extreme point to be measured to, on which this reduction is to be made, which can then be allowed for in the field in the following manner:—suppose the angle of elevation was found to be 14° 30′, on the other side of the arc will be found the figure 3 and a fractional part, which signifies that the chain must be lengthened 3 links and a fraction, or that the chain should be drawn forward on the ground that quantity to bring it to the horizontal measurement. In the common operations of surveying it will be found most advantageous to make the necessary allowance in the field, especially where you cross many fences or take a good quantity of offsets, as it will be found very troublesome in plotting to make the necessary reduction for each distance: but where great accuracy is required, the angle should be noted and the necessary reduction made when plotting the work. Thus, on reference to the table for reducing hypothenusal lines to horizontal, it will be found that a reduction of 3,18 links must be made from each chain's length. Now in the field you could very well allow for the three links on each chain, but not for the decimal parts, which, on a line of any great extent, would make some difference: it should, therefore, depend on the description of work whether the allowance be made in the field or in the office, the latter, as we have observed, being the most correct.

Further information respecting vertical angles will be found in the account of levelling with the theodolite.

Captain Everest's Improved Theodolite.

This instrument differs considerably, and has many decided advantages over those in common use. It is extensively used in India, and is now becoming very common in this country. It is not thought necessary to give a minute description of it, as five minutes' examination of the instrument would more fully explain its advantages than the most lengthened account. This theodolite has three verniers for the horizontal angles, the mean of which is taken, as also of the two for the vertical angles. The whole instrument, in place of being mounted on parallel plates, is fixed on a tripod stand, three foot-screws serving to set it level, and is usually bronzed. The method of adjusting this instrument is somewhat different from other theodolites.

To adjust the Level, so as to make the Axis of the Horizontal Limb truly Vertical.

Bring the spirit-bubble attached to the bar over two of the foot-screws, and by their motion bring the bubble to the centre; then turn the instrument *half* round, when, if the bubble remains in the centre of the tube, it is right; if not, correct half the error by raising or lowering the tube itself, and the other half by one of the foot-screws.

For the Line of Collimation:—After bisecting an object with the vertical wire, the telescope must be reversed, the bisection remaining perfect; if not, correct half the difference by the collimating screws, and the other half by a horizontal motion of the instrument until perfected.

To Correct for the Vertical Arcs:—Take the altitude or depression of any object with the telescope reversed, half the sum will be the true angle to which the verniers must be set, and bring the level connecting the verniers to the centre of its run by the adjustment screws at either end.

The Author has a 5-inch theodolite (which is the most useful size for general purposes) of the above description, made by Troughton and Simms, which performs admirably; but he has found it necessary to adopt parallel plates instead of the tripod (which had a very sensible lateral motion), but has retained the tripod on the instrument, by which means he has the advantages (that of being able to use it without a stand) of the instrument without its defects. Over the verniers are engraved the letters A, B, and C; degrees and minutes being always read from A, and minutes only from B and C, and a mean taken as follows:—

On the instrument being clamped, the reading at

A was	7°	34′	-″
B ,,	-	33	-
C ,,	-	33	-
	7	33	20 mean.

On bisecting the object whose angular distance was required, the reading at A was 45° 59′ -″

A was	45°	59′	-″
B ,,	—	58	-
C ,,	—	59	-
	45	58	40
Subtract	7	33	20
Angle required	38	25	20

The vernier A might be set at 360° in the same manner as described for the common theodolite, and the reading, when an object is bisected, will be the desired angle. Neither is it necessary to read the three verniers if the description of work does not require such accuracy. Theodolites of the above size and description will be found the most useful for all ordinary purposes of surveying; and, moreover, are so light as to be carried about in the field without inconvenience.

Instrumental Parallax.

Parallax is often the cause of as much perplexity in surveying instruments as in those for levelling; for the method of procedure to correct this the reader is referred to the account of levelling instruments in another part of this treatise.

Cross Hairs of the Diaphragm.

If the reader should happen to break these hairs, he will see the method of replacing them in the account of Levelling Instruments.

Theodolite Stand.

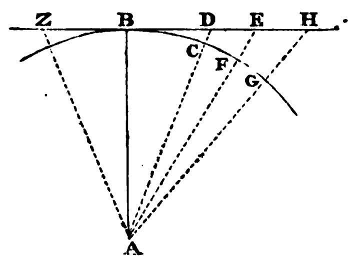
The surveyor is recommended to have a good solid stand for his instrument, similar to that described for levelling instruments; he will thereby avoid the tremulous motion and consequent uncertainty attendant on the use of the round weak legs generally applied to surveying instruments, which would appear to be made rather for show and convenience of carriage, than use; a solid, firm, and immovable mounting for the instrument being a desideratum.

THE

THEORY AND PRINCIPLES OF LEVELLING.

THE figure of the earth is understood to be determined by a surface at every point perpendicular to the direction of gravity, or to the direction of the plumb-line. This surface is the same that the sea would have if continued all round the earth; the surface of every fluid, when at rest, being horizontal or perpendicular to the direction of gravity. Now the visible horizon of an observer at a point on the surface of the earth is a tangent, or at right angles to the direction of gravity at that point. Levelling is, therefore, the finding a line parallel to the horizon, at one or more stations, to determine the height or depth of one place with respect to another; its application is in the laying out of roads, the conducting of water, draining, &c., &c.

Two or more places are on a true level when they are equally distant from the centre of the earth. One place is also higher than another when it is equally distant from the centre of the earth, and a line equally distant from that centre in all its points is the line of true level. But the earth being round, that line must be a curve, and make a part of the earth's circumference, or, at least, be parallel to it, or concentrical with it, as the line B C F G, which has all its points equally distant from A, the centre of the earth, considering it as a perfect globe.



But the line of sight, B D E, &c., given by the operation of levelling is a tangent, or a right line, perpendicular to the semi-diameter of the earth at the point of contact B, rising always higher above the true line of level the farther the distance is, which is called the apparent line of level. Thus C D is the height of the apparent level above the true level, at the distance B C or B D; also E F is the excess of height at F; and G H at G, &c. The difference, it is evident, is always equal to the excess of the secant of the arc of distance above the radius of the earth.

Now the difference C D, between the true and apparent level at any distance, B C or B D, may be found thus:—by a well known property of the circle

(2 A C + C D): B D :: B D : C D, or because the diameter of the earth is so great with respect to the line C D, at all distances to which an operation of levelling commonly extends, that 2 A C may be safely taken for 2 A C + C D in that proportion without any sensible error, it will then be 2 A C : B D :: B D : C D, which therefore is $= \frac{BD^2}{2AC}$ or $\frac{BC^2}{2AC}$ nearly; that is, the difference between the true and apparent level is equal to the square of the distance between the places divided by the diameter of the earth, and, consequently, it is always proportional to the square of the distance. Now the mean diameter of the earth being nearly 7,916 miles,* if we first take B C = 1 mile, then the excess $\frac{BC^2}{2AC}$ becomes $\frac{1}{7916}$ of a mile, which is 8,004 inches, or 6,670 decimals of a foot, for the distance of the apparent above the true level at the distance of one mile.

Hence proportioning the excesses in altitude according to the squares of the distances, the height of the apparent above the true level can be easily ascertained, as for example:—a spirit-level planted on a hill, the horizontal wire of which exactly coincided with the summit of another hill, distant 5 miles, required the difference of level; the height of the levelling telescope above the ground being 4,50 feet and decimals.

* The equatorial diameter of the earth is 7,924 miles, and the polar diameter 7,908 miles; the mean diameter, 7,916 miles, is therefore taken.

Allowance for curvature for 1 mile	6670	
Square of distance; 5 miles	25	
	33350	
	13340	
Amount of curvature for 5 miles	16,6750	
Height of instrument to be added —the observed hill appearing so much higher than where the instrument was planted . .	4,5000	
	21,1750	difference of level.

From this example, although the apparent difference of level is only 4,50 (the height of the instrument) yet the observed hill is actually 21,1750 higher than where the instrument was planted, but, on account of the curvature of the earth, it is apparently depressed to the same level as the centre of the telescope.

But what has been stated has been said without any regard to refraction in elevating the apparent places of objects. But as the operation of refraction, in incurvating, the rays of light proceeding from objects near the horizon, is very considerable, it can by no means be neglected, when the difference between the true and apparent level is estimated at considerable distances. The terrestrial refraction, when the elevation is not very great, varies from $\frac{1}{4}$ to $\frac{1}{24}$ of the angle subtended by the horizontal distance of the objects; and the radius of curvature of the ray, therefore, varies from twice to twelve times the radius of the earth. In the mean state of the atmosphere the refraction is about $\frac{1}{14}$ of the horizontal angle, and the radius of curvature of the ray seven times the radius of the earth. The effect of refraction may be allowed for by computing the correction for curvature, and taking one-seventh of it for the quantity by which the object is rendered by the refraction higher than it ought to be; it must be observed that refraction is opposed to curvature.

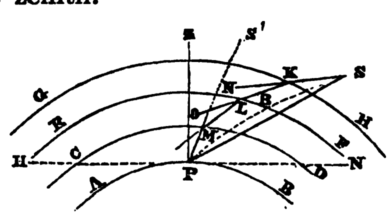
The above example will then stand thus :—

Curvature	16,6750
Deduct for refraction $\frac{1}{7}$....	2,3821
	14,2929
Add height of instrument as before................	4,5000
	18,7929 true difference of level.

The necessary tables containing the correction for curvature and refraction, for distances in chains, feet, and miles, are inserted at the end of this treatise, to which the reader is referred. The corrections for refraction are taken, as in the above example, at $\frac{1}{7}$ of the apparent above the true level, although many professional men allow $\frac{1}{12}$; but it is found to vary with the state of the atmosphere in regard to heat or cold, and humidity, so that determinations obtained for one state of the atmosphere will not answer correctly for another.

Of the Causes which Produce Atmospherical Refraction.

From the nature and progression of light rays, in passing from any object through the atmosphere or part of it to the eye, do not proceed in a right line; the atmosphere being composed of a great number of thin strata of air of different densities, the densities being greater the nearer they are to the surface of the earth, the luminous rays which pass through it are acted on as if they passed successively through media of increasing density, and are therefore inflected more and more towards the earth as the density augments. To explain the nature of refraction let A B be a portion of the earth's surface, G H the upper boundary of the atmosphere, S a star, P the place of the observer, and Z his zenith.



Let E F, C D represent the boundaries of these strata, then a ray of light will proceed from the star S in a straight line until it arrives at the point K, where it enters the denser medium; it will then no longer pursue its direction S K N, but will be deflected in the direction K L; at the point L it enters a still denser medium, and will be again deflected from its direction K L O, and will now proceed in direction L M.

Similar effects will be produced whatever be the media through which the ray passes, and it will at length reach the point P in the line M P. Hence the ray instead of being a straight line, is broken into parts K L, L M, M P; and if we suppose the media through which it passes to be indefinitely increased, and their boundaries to approach each other by spaces extremely small, the parts K L, L M, M P, may be considered as curvilineal, and the course of the ray a curved line as S B P, where P is the place of the observer, H P N his horizon, Z the zenith, and S a star. In this case the ray is no longer considered as passing through different strata of variable density, but through a medium of continually varying density, such as the atmosphere of the earth, whose density is greatest at its surface, and decreases towards the higher regions. In passing through such a medium, a ray of light will be deflected into a curve line, concave towards the earth's surface, and will enter the eye of the observer in the direction of a tangent to that curve. A ray from the star S will therefore not proceed in the straight line S P, but in the direction of the curve line S B P, and to the observer at P the star S will appear as if at S′ in the direction of a straight line which touches the curve at P. The angle S′ P N is therefore the apparent altitude of the star, and the angle S P N its true altitude: their difference, the angle S′ P S will consequently be the refraction.

Similar effects take place with regard to the rays of light by which terrestrial objects are rendered visible. In their passage through the atmosphere they are bent out of their rectilineal direction, and enter the eye of the observer in a curve line, so that the apparent or observed altitude of an object is always greater than its true altitude. The correction for refraction of $\frac{1}{7}$ the amount of curvature as given in the tables, will be found sufficiently correct for every state of the atmosphere except in very extensive trigonometrical operations—when it is usual to correct for refraction according to the state of the atmosphere at the time the observations were taken—for the method of doing which the reader whom it concerns is referred to the account by Colonel Mudge of the Trigonometrical Survey of England.

The following form may be adopted for making the corrections for curvature :—reject the decimal 004, and assume the difference between the true and apparent level for one mile, to be exactly eight inches, then arises the following form :—

$$\text{Correction} = \frac{2\,D^2}{3}$$

D being the distance in miles, or in other words two-thirds of the square of the distance in miles, will be the amount of correction in feet.

Another convenient form for making the correction for curvature for *any* distance is—to add to the arithmetical complement of the logarithm of the diameter of the earth,* or 2,378861—double the logarithm of the distance in feet, the sum will be the logarithm of the correction in feet and decimals, from which, if $\frac{1}{7}$ of itself be subtracted, the result will be the combined correction for curvature and refraction.

Example. Required the amount of curvature for 1350 feet:—

Log. of 1350 feet	3,130334
	2
	6,260668
Add arithmetical complement of the log. of the diameter of the earth	2,378861
Log. of ,04361 . .	8,639529

Correction for curvature for 1350 feet ,04361 decimals of a foot.

But the most convenient method of making the correction for curvature, is to divide the square

* The arithmetical complement of a logarithm is what the logarithm wants of 10,00000, &c.. and the easiest way to find it, is beginning at the left hand, to subtract every figure from 9 and the last from 10. Thus the diameter of the earth is 41,796480 feet, the logarithm of which is 7,621139 which subtracted from 10,00000 gives 2,378861 the arithmetical complement.

of the distance in chains by 800; the quotient will be the depression in inches very nearly.

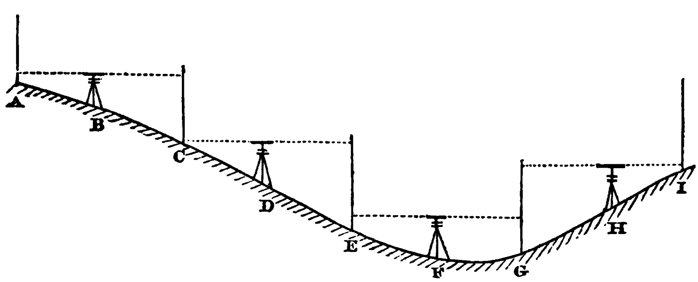
But previous to introducing the reader to practical levelling, it will be as well to inform him, that in the common practice of levelling, neither curvature or refraction are ever allowed for, as by the simple expedient of taking observations at equal distances on each side your instrument, both stations are equally affected. Suppose your instrument planted at B (see first Diagram) and your points of observations to be Z and D, which are equal distances from B, it is evident both would be affected alike—or, in other words, the points would be equally distant from the earth's centre. Suppose further—the instrument planted at B as before—one point of observation being Z and the other E, curvature would be allowed for on D E, or the excess of distance of the point E above that at Z. It is only in experiments or very delicate operations, that its effects can be appreciated, or in extensive trigonometrical surveys, where the observed distance is generally several miles; but this can never be the case in common levelling operations; the average distance to which levelling at one sight extends, seldom exceeding a few chains.

THE

PRACTICE OF LEVELLING.

LEVELLING is an art of great practical utility, and with the beautiful instruments now in use, the exact difference of level between any number of places may be obtained, with a degree of accuracy surprising to those unacquainted with the delicate adjustments of those instruments.

It will be at once apparent, that to obtain the difference of level between any number of places, that they must all have reference to some fixed mark, from which an imaginary line called the *datum* is drawn, and upon which all the levels are based; or, in other words, every variation in the surface of the ground is reckoned from this assumed line, which is generally either high-water spring tides (Trinity datum), or low-water spring tides; or if very remote from the sea, some fixed mark is chosen at either end of the line of levels to which they are all referred. If it should be thought advisable to fix the datum line lower than either end, it may be done by assuming a line 100 or any number of feet lower than the fixed mark, on which assumed datum line the levels will be based. But reference should be made to the tides if practicable where the line of levels are of great extent. There are two instruments necessary to obtaining the difference of level between two or more points: first, the spirit-level, which, by mechanical contrivances hereafter described, is set truly horizontal: secondly, a graduated rod or staff, which is alternately advanced with the spirit level, denoting by the graduations bisected, the rise or fall between any two points. (See description of the Spirit-Level.) An example will immediately illustrate this :—



Let it be required to know the difference of level between the points A and I. The spirit level is set up at a point B, and the staff at A, and when, by the mechanical means previously spoken of, the spirit-level is brought truly horizontal, on looking through the telescope attached to it, the line of sight will be the dotted line towards the staff at A, which is graduated sufficiently distinct to be read off with the aid of the telescope. Suppose the line of sight cuts the staff at 4 feet; the spirit-level revolving on its stand is turned in the direction of the staff at C, and being still perfectly horizontal, it bisects it at 7 feet 6 inches, the difference then between the points A and C will be 4 feet, minus 7 feet 6 inches, or equal to a fall from A to C of 3 feet 6 inches. The spirit-level is then removed from B, and placed at D, the staff remaining at C, the spirit-level, as before, being set truly horizontal, is turned in the direction of the staff at C, which it bisects at 2 feet; it is then turned towards E, which it bisects at 9 feet, the difference of level between the points C and E will be 2 feet, minus 9 feet, or equal to a fall of 7 feet from C to D; which, added to the previous fall of 3 feet 6 inches from A to C, will, on the whole, be equal to a fall of 10 feet 6 inches from A to E. The spirit-level being removed to F, and the staff placed alternately at E and G, reads at the former 4 feet, and at the latter 7 feet, which is a further fall of 3 feet from E to G, making altogether from E to G a fall of 13 feet 6 inches. We now place the spirit-level at H, and read on the staff at G 6 feet, and on the staff at I only 2 feet 6 inches, or equal to a rise of 3 feet 6 inches from G to I. This, instead of being added to the fall of 13 feet 6 inches, is (being a rise) to be deducted from it—then 13 feet 6 inches, minus 3 feet 6 inches, (the rise from G to I) will be equal to 10 feet, which is the difference of level between A and I, and this method of procedure may be continued for any distance, adding or subtracting, as the ground rises or falls. If it was only necessary to obtain the difference of level between the extreme points A and I, it would not be requisite to reduce the levels of the several intermediate stations, but arrange the fore and back sights into separate columns, and the difference of their sums would be the difference of level—thus

	Ft. In.			Ft. In.	
A - . -	4 . 0	- . - × - . -		7 . 6	- . - C
C - . -	2 . 0	- . - × - . -		9 . 0	- . - E
E - . -	4 . 0	- . - × - . -		7 . 0	- . - G
G - . -	6 . 0	- . - × - . -		2 . 6	- . - I
Sum of back sights	16 . 0	Sum of fore sights		26 . 0	
				16 . 0	
Difference of level between A and I .				10 . 0	

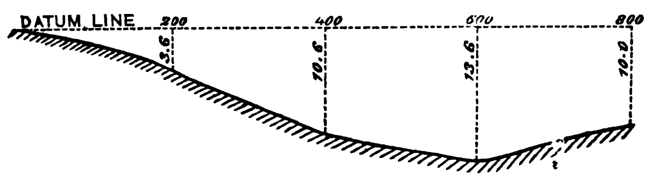
But to be able to draw the section so as to show the undulation of the ground between the points A and I, it will be necessary to measure the distances between A and C, C and E, &c., so that the staff being set up at each change of inclination of the ground, and having the distances from staff to staff, you can proceed to plot the section. But in this case the form of field-book would be similar to the following, the difference between the back and fore sights being in each case added to, or subtracted from, the preceding reduced level ;

and to prove the correctness of the castings, it is necessary to add up the columns of the fore and back sights (as in the example above), and if their difference equals the last reduced level, it shows it to be correct.

Field-Book.

B. Sights.	F. Sights.	Red. Levels.	Distances.	Remarks.
		0,00	0,00	Datum.
4,0	7,6	3,6	2,00	
2,0	9,0	10,6	4,00	
4,0	7,0	13,6	6,00	
,0	2,6	10,0	8,00	
16,0	26,0			
	16,0			
	10,0	Difference, the same as last reduced level.		

You have thus the materials before you for drawing the section, as in the column containing the reduced levels (taking the level of the ground at A as the datum) you have a fall of 3 feet 6 inches at 2 chains from A; and at 4 chains (the distances being continuous) you have a fall of 10 feet 6 inches below your starting point. You will thus continue it until you have plotted the result of each observation, first marking off the distances on the datum line, and then the reduced levels answering to such distances:—the method pursued in plotting a section will be immediately understood on reference to the following diagram, which is the plotted section of the example given, the horizontal scale being 2 chains and a half to 1 inch, and the vertical scale 20 feet to 1 inch. We should here observe that the vertical scale to which a section is plotted is *always different* to the horizontal: if it was not the case, the variations of the ground would be scarcely perceptible.

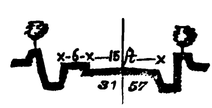
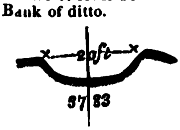


Thinking that the student has now received sufficient insight into the principles of levelling, we will here give an example, with the forms of field-book made use of by practical men, which alone are useful; the description, adjustments, and method of using the different levelling instruments being given hereafter.

The more simple the form can be reduced to, the less liable to errors and confusion. The following is the most simple that we are acquainted with, in which all the levels may be cast out in the field, by which means much time is saved in the office, and little remains to be done, but plot the section.

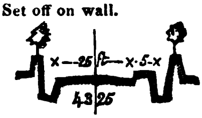
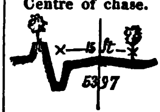
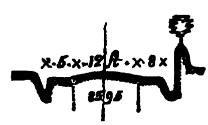
The following example is part of a contract section taken for a railway. The distances were measured with a 100-feet chain, consequently the quantities in the distance column are feet. The section (plate 7) is plotted to a scale of 5 chains to the inch, for which purpose a scale divided into 330 to the inch was used, that number of feet being contained in 5 chains.

Field-Book.

Elevation.	Back Set.	Fore Set.	Depression.	Total Rise.	Distance.	REMARKS.
				80,96	B.M.	Height above Trinity Datum.
1,11	6,84	5,73		82,07	0,00	Level of ground at B. M.
	5,73	8,10	2,37	79,70	,15	
	8,10	8,15	,05	79,65	,45	
2,35	8,15	5,80		82,00	,50	
,80	5,80	5,00		82,80	1,10	
,45	5,00	4,55		83,25	2,17	
,96	5,01	4,05		84,21	2,60	
	4,05	4,98	,93	83,28	4,00	
	4,98	6,12	1,14	82,14	5,00	
	6,12	6,67	,55	81,59	6,00	
	2,25	7,77	5,52	76.07	8,00	
	7,77	13,52	5,75	70,32	10,00	
	3,95	6,30	2,35	67,97	11,00	
	6,30	10,80	4,50	63,47	12,00	
	1,60	4,24	2,64	60,83	13,00	
	4,24	6,74	2,50	58,33	14,00	
	6,74	10,20	3,46	54,87	16,00	
	2,17	4,60	2,43	52,44	18,00	
	4,60	5,36	,76	51,68	20,00	
	5,36	5,99	,63	51,05	21,00	
	4,49	5,62	1,13	49,92	23,00	
	5,62	7,57	1,95	47,97	25,00	
	3,16	4,58	1,42	46,55	27,00	
	4,58	4.92	,34	46,21	28,00	
	4,92	5,20	.28	45,93	29,00	
	5,20	6,19	,99	44,94	30,00	
	4,02	5,21	1,19	43,75	31,30	
	5,21	6,08	,87	42,88	31,57	Centre of road.
,92	6,08	5,16		43,80	31,80	
	5,16	9,27	4,11	39,69	33,50	
	2,55	5,30	2,75	36,94	B.M.	On bottom hook of gate.
	5,30	6,15	,85	36,09	35,00	
	6,15	8,73	2,58	33,51	36,00	
	8,73	12,52	3,79	29,72	37,30	
,70	5,90	5,20		30,42	37,72	On bank of river.
	5,20	9,60	4,40	26,02	37,83	Centre of river-bed.
4,66	9,60	4,94		30,68	37,92	Bank of ditto.
1,96	4,94	2,98		32,64	B.M.	
	2,98	6,60	3,62	29,02	38,60	
	6,60	6,61	,01	29,01	40,00	
,85	8,70	7,85		29,86	41,00	
2,33	7,85	5,52		32,19	42,00	

[Carried forward.

Field-Book continued:—

Elevation.	Back Set.	Fore Set.	Depression.	Total Rise.	Distances.	REMARKS.
1,98	5,52	3,54		34,17	43,00	Side of road.
	7,29	8,10	,81	33,36	43,25	Centre of do.
	8,10	8,20	,10	33,26	43,50	Side of do.
4,33	8,20	3,87		37,59	B.M.	Set off on wall.
	3,97	4,78	,91	36,68	45,00	
1,23	4,78	3,55		37,91	46,00	
1,28	3,55	2,27		39,19	47,00	
,72	6,72	6,00		39,91	48,00	
,24	6,00	5,76		40,15	49,10	
1,60	5,76	4,16		41,75	51,00	
1,21	7,36	6,15		42,96	53,00	
1,25	6,15	4,90		44,21	53,80	
	4,90	6,28	1,38	42,83	53,97	Centre of chase.
,08	6,28	6,20		42,91	55,00	
,45	6,20	5,75		43,36	56,00	
	4,70	4,72	,02	43,34	59,00	
,83	4,72	3,89		44,17	61,00	
,48	5,81	5,33		44,65	63,00	
,83	5,33	4,50		45,48	66,00	
,08	4,50	4,42		45,56	67,00	
,55	6,00	5,45		46,11	69,00	
,12	5,45	5,33		46,23	71,00	
	5,33	5,71	,38	45,85	73,00	
	3,30	4,75	1,45	44,40	74,60	
	4,75	6,12	1,37	43,03	75,50	
	6,12	7,09	,97	42,06	77,00	
	4,23	4,94	,71	41,35	81,00	
	4,55	5,18	,63	40,72	83,00	
	4,74	5,14	,40	40,32	85,60	
,36	5,14	4,78		40,68	85,95	Centre of road.
	4,78	5,10	,32	40,36	B.M.	
34,71	397,83	438,43	75,31	|		
		397,83	34,71	80,96	- -	Height of first B. M., deduct from last reduced level.
		40,60	40,60	40,60		

The method of procedure in setting down, casting out, and reducing the levels in the above form of field-book, will be easily understood on reference thereto. In the second and third columns are entered the back and fore sights, opposite to each other: the first contains the difference of the two, if a rise; if a fall, it is entered in the fourth,* the differences in this form

* When the difference of columns 2 and 3 have been cast out, the four columns should always be added up at each page, previous to reducing or carrying the difference to column 5: the total rise or fall will correspond, if

being set down in the order they are cast out. The fifth contains the reduced levels, obtained by adding or subtracting the differences to the previous reduced level; the sixth the distance (which will be perceived is continued from the commencement to the end of the section); and the last, which is the largest, for remarks, to note the crossings of roads, rivers, brooks, &c., and, if necessary, to enter the bearing of your line of levels; but in the above case no bearings were taken, as the ground had been surveyed, and the line definitely marked out. In the forms of field-books generally used there is a separate column for the bearing at each station, which is quite useless; it is sometimes, indeed, necessary in running trial levels through a part of the country you are unacquainted with, to note the bearing of any object you may be running to; and when you change the direction of your line, again note the bearing with the chainage, so that you may be enabled to lay down on a map the line you have been taking; but it will not be necessary for you to note the bearing any oftener than you change your general direction.

The sketches of the crossings of roads, rivers, &c. in the fifth column need no explanation; they are plotted to a large scale on the section, and will be found of infinite service to the engineer in guiding him as to the dimensions of his bridges, so as to maintain a proper width of roadway, &c.

correct; the reduced level must also correspond by deducting the quantity brought forward at the commencement of each page.

The above example of a field-book comprises all the data requisite or necessary for drawing a contract section, for which purpose it was taken. The levels are based on Trinity datum, which was previously ascertained, and bench marks left at each end. To show with what correctness levelling operations may be carried on, it will be only necessary to state, that the difference between the bench marks at each end, from that previously ascertained, amounted to 0,02 only, or two-hundredths of a foot, the staff being graduated decimally.

The plotted section from the above field-book is given at the end of this treatise, by referring to which, and carefully looking over the field-book, the student will become perfectly acquainted with every particular necessary for the purpose. Where the ground slopes transversely, it becomes necessary to take cross sections at intervals, but in the above, the ground laid so fair it was not at all requisite. It is also necessary to take the section of every road, lane, or public way over or under which it is intended to build a bridge, for four or five chains or more on each side of the point of crossing, as you will then be able to judge of the best method of crossing it, and be able to show the requisite quantity of cutting or embankment, in carrying the road under or over the railway. Curvature is never allowed for in practice, except in the most delicate operations, as although the instrument may not always be midway between the stations, yet a mean of a number of observations will give the true level, provided the inclination of the ground be not continuous; but even so, if the operation of levelling is properly conducted, the errors from this source would be too trivial to be noticed. In the method of allowing for curvature, the student is referred to the introductory chapter. But it should be observed, that it is always *desirable* in levelling operations, to place the staff as near equal distances (roughly estimating it with the eye) on each side of the instrument as can be done conveniently; which (if the instrument should be out of adjustment) will neutralize the errors thereby occasioned: *although, if the adjustments are perfect, it is not necessary to ensure accurate results, that the staff should be placed at equal distances. In practice, the operator generally chooses the most commanding spot of ground on which to plant his instrument, without regard to its being in a line with the staffs, or at equal distances;* although, as we have before observed, it should be attended to when it can be done conveniently.

We should here remark, that it is always preferable to use one staff only, on account of the difference of the graduations, although made by the same person with ever so much care. We have frequently, when adjusting our instrument, found a difference of $\frac{1}{100}$ of a foot in the readings of two staves, although made by the same person, and no doubt the errors are often much greater. To avoid this source of error, we would

Trial Levels.

The manner of taking trial sections, where there are several lines to be levelled for the purpose of ascertaining the best, is so similar to the example of levelling already given, as to be scarcely worth introducing; but as many surveyors or students would, perhaps, from the minute data given in the example, be apt to think the same necessary in every case, we have thought it best to give an account (with examples) of this kind of levelling.

The object in taking trial sections, is to ascertain generally the best of several lines, for which purpose it is not necessary or requisite to show every trifling variation in the ground, but only the general features of the line over which you are passing; as in all cases where trial sections are taken, the levels are taken anew over the particular line decided on, but even then it is not at all necessary to give the minute particulars as contained in the previous example, the sights being taken as far as the instrument will command backwards and forwards within limits; of course sudden rises or falls must be shown, but the surveyor must bear in mind that he is not taking a working section, which can only be done when the line is definitely marked out on the ground: a lateral difference of only a few feet from the intended line when not staked out (which in most cases cannot be avoided), will generally make the minute details of a section quite different from that obtained when the centre line shall be accurately set out. The surveyor will, therefore, see the folly in wasting his time in those particulars which must, under the circumstances, be useless.

The accompanying sections were taken for the same line of railway, although some by the different routes taken are much longer than others. The method of plotting these sections for the purpose of comparison is obvious; they are all based on the same datum line, the same bench marks being referred to at the termination, as well as the commencement of each line, for the purpose of testing the accuracy of the levels taken for each section, which, if practicable, *should always be done.* It was not known at the time how much above Trinity datum the point of commencement was, no bench mark having been fixed; one was accordingly left, which was assumed as 100 feet above it, to which all the levels were reduced and plotted.

It was afterwards ascertained that the height of the B. M. was 115 feet above T. D., being 15 feet higher than that assumed; it only then required a line to be drawn on the section 15 feet below that assumed to give the correct datum; and by adding the difference of 15 feet to any reduced level in the field-book, of course the exact height of that point would be given without reference to the section.

By tinting the surface of each section a different colour, their merits are at once determined without confusion. The field-book of the section tinted brown is only given as being sufficient for the purpose. The page at which you commence your levels should be headed somewhat in the following manner:—Trial Levels for the — Railway or Canal, as it may be, from (the name of the place you commence at, to the place you are to finish), with the date, name of the engineer, and any other particulars that may occur to you.

Field-Book.

The B.M. assumed 100 *feet above Trinity Datum—Distances in Chains.*

Elevation.	Back Set.	Fore Set.	Depression.	Total Rise.	Distance.	REMARKS.
				100,00	0,00	B. M. on root of tree.
7,86	9,20	1,34		107,86	2,00	
10,89	11,32	,43		118,75	3,70	
9,64	11,24	1,60		128,39	6,00	
	7,80	10,68	2,88	125,51	10,00	
	2,76	7,16	4,40	121,11	18,00	
7,27	9,22	1,95		128,38	28,00	
	4,38	7,06	2,68	125,70	37,50	Side of road.
	4,10	5,30	1,20	124,50	38,00	Centre of turnpike road from — to London, width 100.
	5,30	10,78	5,48	119,02	38,50	Side of road.
2,30	7,35	5,05		121,32	46,00	
3,32	11,36	8,04		124,64	55,00	
	4,55	10,00	5,45	119,19	61,00	
	2,20	10,43	8,23	110,96	63,50	
	,42	11,90	11,48	99,48	64,80	
	,49	11,46	10,97	88,51	65,50	
	,90	15,00	14,10	74,41	67,00	
14,42	15,00	,58		88,83	70,00	
9,41	10,84	1,43		98,24	73,00	
9,18	11,34	2,16		107,42	75,00	
7,85	10,75	2,90		115,27	79,00	
6,88	10,88	4,00		122,15	83,00	
						—1 Mile.
	4,00	9,36	5,36	116,79	7,00	
	1,32	8,86	7,54	109,25	B.M.	Top of style.
	,70	3,00	2,30	106,95	11,50	
	3,00	5,22	2,22	104,73	16,50	Side of road.

[Carried forward.

Field-Book continued:—

Elevation.	Back Set.	Fore Set.	Depression.	Total Rise.	Distance.	REMARKS.
3,75	5,22	1,47		108,48	17,00	Centre of road, width 50.
7,44	9,28	1,84		115,92	18 00	Side of road.
7,98	10,92	2,94		123,90	23,00	
	3,53	9,07	5,54	118,36	26,00	Side of road.
2,89	4,19	1,30		121,25	B.M.	On bottom hook of gate.
	1,30	10,47	9,17	112,08	27,00	Centre of road, width 40.
	1,84	5,00	3,16	108,92	27,50	Side of road.
	5,00	11,77	6,77	102,15	30,00	
	,58	11,07	10,49	91,66	35,00	
	1,93	12,35	10,42	81,24	37,00	
	1,19	11,52	10,33	70,91	40,00	
	1,08	9,10	8,02	62.89	46,00	
5,10	8,90	3,80		67,99	54,00	
	3,80	11,70	7,90	60,09	57,00	
	1,85	11,12	9,27	50,82	61,00	
	2,78	8,20	5,42	45,40	64,00	
	8,20	9,12	,92	44,48	70,00	
3,57	5,85	2,28		48,05	79.00	Side of road.
,05	5,05	5,00		48,10	80,00	Centre of road at — width 100.
					——	—2 Miles.
1,50	5,00	3,50		49.60	,50	Side of road.
	3,50	11,66	8,16	41,44	6,00	
	2,90	8,10	5,20	36,24	10,00	
	8,10	10,90	2,80	33,44	14,00	
	1,78	7,15	5,37	28,07	24,00	Occupation road, level with adjoining fields.
2,01	7,15	5,14		30,08	30,00	
9,00	9,50	,50		39.08	38,00	
5,82	8,00	2,18		44,90	45,00	47,50. Occupation road, level with adjoining fields.
,29	6,45	6,16		45,19	57,00	
1,41	7,95	6,54		46,60	B.M.	Bottom hook of gate.
2,54	6,54	4,00		49,14	63,00	
	4,00	8,92	4,92	44,22	64,00	Centre of lane, width 30.
5,50	8,92	3,42		49,72	65,00	
4,43	8,27	3,84		54,15	73,00	
8,24	10,37	2,13		62,39	79,00	
	8,68	12,14	3,46	58,93	85,00	
					——	—3 Miles.
	2,13	11,73	9,60	49,33	9,50	In road, side of park.
5,70	8,90	3,20		55,03	B.M.	Bottom hook of lodge gate.
2,20	3,20	1,00		57,23	16,00	
	1,00	3,45	2,45	54,78	20,00	
	5,38	9,47	4,09	50,69	29,00	
	3,08	5,20	2,12	48,57	35,00	In lane, level with fields.
	5,20	5,87	,67	47,90	42,00	
7,36	9,14	1,78		55,26	46,00	
	1,78	7,65	5,87	49,39	52,00	
	2,10	11,85	9,75	39,64	56,00	
	1,24	10,75	9,51	30,13	B.M.	Bottom hook of gate.
174,30	384,67	454,54 384.67	244,17 174,30	100,00	- -	Assumed level of first B. M., deduct from last reduced level.
		69,87	69,87	69,87		

The section (pl. 8) is plotted from the above field-book to a scale of 4 in. to the mile horizontal (which is 20 chains to the in.), and 50 ft. to the in. vertical.

The roads, &c. written on the section refer to that tinted brown. If the roads, &c. of those tinted red and blue had been written in, it would have been done with the same colours as the respective sections are tinted with. The distances in miles, and also the vertical and horizontal scales, should be written on the section. Many engineers also require the horizontal distances and vertical heights to be figured, which is a check on the accuracy of the plotting.

At crossing all roads, lanes, rivers, brooks, &c. the local names should be ascertained and written on the section; also the names of places to and from which the roads lead; in fact, *too much information cannot be obtained:* what at the time often appears trifling becomes afterwards a matter of great importance. It would be as well also to note in your book the description and quality of land over which you pass, whether clay, gravel, chalk, &c., &c., and whether ballasting can be had, as on these particulars often depends the eligibility of any particular line.

Check Levels.

When the trial levels are taken, and the line decided on, it is again levelled, but with more care. At various points are left bench marks (generally about every two miles) which, if not previously determined on, are very minutely described by the person leaving them (a distinguishing mark being left to enable the person coming after to find it with greater facility). To be certain that no errors have been committed in taking the section, it is usual for some other person to check the work by ascertaining the difference of level between the various bench marks. If these differences of level prove to be the same as before, or nearly so, it is fairly to be inferred that the intermediate levels forming the section are also correct.

The person taking the check levels does not pass over the line on which the section was taken, but proceeds by the nearest and most convenient route from bench mark to bench mark, generally by a road if running near; not noticing the variation of the ground, and taking as moderate long sights as his instrument and the ground will permit. No chain is required in this kind of levelling, but the surveyor should be careful to plant his stave (as near as his eye will direct him) at equal distances on each side of his instrument: errors arising from curvature, long sights, &c. will then be nugatory. The section tinted brown was decided on as the best, but there was not time to level it over again, and the trial section was obliged to be deposited with the Clerk of the Peace, but which should never be done when by any possibility it can be avoided. But whatever it wanted in detail it was necessary to have the general results correct, for which purpose check levels were taken to various bench marks, but not to all that were left, which would have been a waste of time, but only to those that were conveniently situated, or of material consequence, *as the crossing of a summit, or any particular road or point on the line, to which reference might be made.* The first bench mark on the line that was levelled to, was that at the style, which was not at all necessary, being so short a distance from the commencement, but as it laid very convenient it was taken.

The check levels up to that point are given, which will explain the method.

Field-Book.

Check Levels from B. M. on Root of Tree, assumed 100 *feet above Trinity Datum.*

Elevation.	Back Set.	Fore Set.	Depression.	Total Rise.	Distance.	REMARKS.
				100,00	- -	B. M. above Datum.
	8,60	2,20				
	9,45	3,20				
	5,40	1,80				
	4,51	9.27				
	4,86	8,25				
	13,40	10,52				
	5,60	6,90				
	5,80	9,43				
	8,83	5,64	- -	109,24	- -	B. M. on Style.
	66,45	57,21				
	57,21					
	9,24	Difference of Bench Marks.				

It will be seen on reference to the former field-book, in which the height of the B. M. at the style is entered, that the difference of the two levellings was but $\frac{1}{100}$ of a foot. It was, therefore, assumed that the intermediate levels were correct, and in this manner were the check levels taken over the whole line. The results may be obtained by casting out the differences of each observation (but not reducing them), and adding up the several columns to prove each other; or, as it is generally done by simply casting up the back and fore sights, and subtracting the one from the other, being satisfied of the correctness of such addition by casting the columns a second time, commencing from the top.

The same form of field-book is here given as for the other sections, although but two columns are required, but it is presumed that the surveyor has his field-book ruled throughout in the same manner.

Example in Levelling with Plotted Cross Sections.
(Plate 8.*)*

As we have observed in the directions for taking a working section, where the ground is at all sideling, cross sections must be taken at right angles to the main line.

We need only refer to the plate in this case, it being so plain as scarce to need a description. We have omitted the field-book as being unnecessary, the levels of the main line being taken in the same manner as already described. The cross sections were taken at the same time as the main line, and in the following manner:—On bringing the levels up to any point of the line where we thought it was necessary to take a cross section, we drove in a stake, level with the ground, and placed the staff on it; then, without removing the instrument, we read a staff placed at several points at right angles to the main line on each side the stake, measuring the distances. The method of plotting is obvious, the point where these cross sections intersect the main line becomes a temporary B. M., and the rise or fall on each side is plotted from a datum line drawn through that point at right angles thereto.

The surveyor will, where the line is staked out, generally be able to command the ground on each side as far as required, without removing his instrument, and can then continue the principal section as usual. He will thus, by exercising his judgment in the planting of his instrument, be enabled to take the cross sections, wherever requisite, without any additional trouble or loss of time. Some engineers like their cross sections plotted above the main line, as at A—this method is perhaps the best.

ON CHAINING.

WITH METHODS OF PASSING WOODS, RIVERS, AND OVERCOMING DIFFICULTIES THAT OCCUR IN LEVELLING.

It often happens that in taking any considerable length of section that difficulties intervene, as woods, lakes, private grounds, forbidden property, high walls, &c., in which case the surveyor is often puzzled how to proceed.

In some recent levelling operations in which we were engaged, in crossing some private property a very high wall intervened, which apparently put a stop to further proceedings, at least in a straight line. To plant the instrument in any position so as to look over the wall was impossible; and to level round to the opposite side would have taken too much time, the distance being nearly a mile, and expedition absolutely requisite; it was also necessary that the levels should be taken with the greatest accuracy. If an inch or two difference in the levels had been of no consequence this difficulty would have been easily overcome by measuring from the top of the wall, or counting the courses of bricks cut by the line of sight on each side. We removed the earth (which was only a few inches), from the side of the wall, to the upper course of footings, and placed the staff thereon; we then clambered over the wall, and, exactly on the opposite side, cleared the earth away in the same manner to the footings, which was about a couple of feet deep; placed the staff thereon, as on the opposite side, calling the reading the same, and then proceeded in the usual manner with the section. We subsequently levelled round to the opposite side of the wall, having left marks for that purpose, when we found the reading of the staff placed on the footings to be exactly the same on both sides.

It will also often happen that in taking a section you come to woods, or private grounds, through which you cannot pass; it will then be necessary to level round to the opposite side, until you come to the spot you would have arrived at had you continued on without any obstruction; but in case you have not a plan of the ground, and cannot see the opposite point at which you would have arrived had you continued on, it will be necessary to measure round it, *in as few lines as possible*, taking the angles with your compass, but if you should not have one to your instrument you must take the angles with the chain in the manner described for surveying a field without a diagonal. When you think you have measured far enough round, you must plot these lines; then, by laying down on this plot the line you were taking previous to such obstruction, you will see at what point you would have come out; apply your scale to it, enter the distance in your book, bring your levels round to that point, and continue the section. By setting your instrument to the same bearing at this point as on the opposite side, your direction will be plainly pointed out.

If you come to a lake or pond, the operation will still be more easy, by simply turning at right angles to the right or left of your line, noting the exact distance, until you can clear the obstruction; then turn at another right angle, and measure the distance forward (which will be parallel to the line you would have measured, had not the obstruction existed) until you get clear, then by turning at another right angle, and measuring out the same distance as at first, it is evident you will come to the same spot you would have arrived at, had you continued your line forward unbroken. This method may be adopted where you come in contact with buildings, or small pieces of wood-land, and generally where the object to be avoided is not of great extent—if so, it is attended with great uncertainty, and should never be practised, but recourse had to the method pointed out above. If you avoid the object by means of right angles, you should not judge of such angles by your eye, but measure them with a sextant or an optical square, which is a small instrument, with the glasses of the sextant reflecting a constant angle of 90°. If you have no such instrument, nor a compass, you must trust to your eye, and, for short distances, may generally set it off correct enough; but for any considerable distance, accuracy cannot be expected. (See Parish Surveying).

For the method of taking inaccessible distances with the chain only, as the crossing of a river, &c., the reader is referred to the part of the work on "Surveying," where he will find every information.

Levelling with the Theodolite.

In levelling operations, where despatch is more essential than results of extreme accuracy, or to take cross sections where the ground is precipitous, the theodolite may be used with great advantage. The manner of applying the theodolite to the purposes of levelling is by taking a series of vertical angles; and in the absence of the spirit level it may be used in a similar manner to that instrument by clamping the vertical arc at zero, setting it up at each change of level, and taking back and fore sights, exactly in the manner described for using the spirit-level: but the manner in which it is principally used in levelling operations is, by taking a series of vertical angles along the proposed line; but it is absolutely necessary, in this kind of levelling, that your instrument be adjusted to the greatest nicety, as on the extreme accuracy of its performance, and the great care of the observer, every thing depends; any inattentiveness on the part of the observer, or carelessness in adjusting his instrument, will make the results worthless.

The line being determined on over which you purpose taking a section, you must set up your theodolite at the commencement (the adjustments, as explained in the chapter devoted to that instrument, having been carefully attended to), and level it by means of the parallel plate screws. Then ascertain the exact height of the optical axis of the telescope, which is best done by measuring to the céntre of the eye-piece; a vane staff must be used, and the vane set carefully to this height. An assistant must now pass along the line (not regarding the intermediate undulations of the surface) until the general inclination of the ground changes, at which spot he must fix it. The telescope must now be moved in a vertical plane, until the bisection of the vane on the staff by the cross wires is perfect, but to ensure accuracy the instrument and staff should change places, and the angle be observed as before; if there is any difference, a mean must be taken, to which the instrument must be set, and clamped. An assistant may now commence chaining the distance, and at each change of level in the surface of the ground, as in common levelling operations, erect the staff, and slide the vane up until bisected by the cross-wires of the telescope, when it will be in the imaginary line connecting the instrument with the staff first erected. Your assistant must then enter the distance, and the height of the vane on the staff, in his book, and continue the chainage onward until a further change in the ground requires the staff to be again erected, and so on to the end.

The most simple method of applying the data thus obtained is to prick off the observed vertical angle, which is the line of sight, and draw it in; on this line mark off the measured distances, from which let fall perpendiculars to the horizon, of the lengths denoted by the vane at the various intermediate stations; a line being traced from the extremities of such perpendiculars will represent the surface of the ground; and these perpendiculars being continued until met by a horizontal line drawn from the point at which the instrument was first set up, or any assumed datum, will show the changes of level at the various points: but the most correct method is to calculate the difference of level between the stations, which may be done in the following easy manner, by the aid of a table of logarithms and logarithmic sines—the measured distance being the hypothenuse of a right-angled triangle:—*To the log. sin. of the observed angle add the logarithm of the measured distance, and their sum, deducting* 10 *from the index, will be the log. of the difference of level;* as for example, suppose the angle of elevation to be 2° 40′; and when the instrument and staff changed places, the angle of depression (which it would then be) to be

2° 42′, the mean 2° 41′ would be taken, and the measured distance to be 7,500 feet.

Log. sin.	2° 41′ . . .	8,670393
Log.	7500 . . .	3,875061
	Log. of 351,018 . . .	2,545454

Showing the difference of level to be 351 feet.

Or the difference of level may be found thus, which is perhaps the most ready method: *from a table of natural sines, take the sine of the angle, and multiply the hypothenuse (or measured distance) by it, which will be the difference required. The base may be also found by taking from the same table the cosine of the angle, and multiplying it by the hypothenuse.* In the above example, the distance being so great, the necessary correction for curvature and refraction must be applied, but the angle being so small, the correction may be applied to the measured distance without sensible error, the hypothenuse and base being nearly the same. The example will then stand thus:—

		Feet.
Observed difference of level		351,018
Correction for Curvature . . .	1,35	
,, Refraction . . .	,19	
		1,160
True difference of level . .		352,178

In taking a section with a theodolite, it would be desirable to take only a very few intermediate observations between your stations, it would then be best to calculate the bases and difference of level for each observation in the manner already described, of course adding to or subtracting from the calculated difference, the difference between the ground where the instrument is planted, and each intermediate station below the line of sight as given by the sliding vane.

Field-Book.

Angle.		INTERMEDIATES.			Hypothenus.	Bases.	Elevation.	Depression.	Red. Level.	Observations.
E.	D.	Hypo.	Diff.	Bases.						
									100,00	Assum. Da.
8°30		5,05	− 10,0	4,995			64,64		164,64	
		10,20	+ 2,5	10,088			153,3		253,30	
		14,59	− 12,3	14,341			202,0		302,00	
					18,80	18,5936	277,88			
			Add	for curva	ture and	refracti	on . . 07			
							277,95		377,95	Abo. Da. at Sta. 1.
	5°42	6,00	+ 3,0	5,970				56,59	321,36	
		9,00	- -	8,956				89,38	288,57	
		13,45	− 14,5	13,384				148,1	229,85	
		19,20	− 8,0	19,105				198,7	179,25	
					22,60	22,4884		224,463		
				Add	for curva	ture and	refracti	on . 103		
						41,0810		224,566	153,384	Abo. a. at Sta. 2.

The plotted section of the above field-book is contained in plate 8; the scales are 330 feet horizontal, 100 vertical.

Columns 1 and 2 contain the angles of elevation and depression; col. 6 the hypothenuse, or measured distances of the stations; col. 7 the bases answering to the hypothenuses in 6; cols. 3 and 5 contain the hypothenuses and bases of the intermediate stations; col. 4, the difference of the intermediate stations below the line of sight; as for example :—at 5,05 the vane on the staff was at 14 feet when bisected, the instrument being set up 4 feet above the ground, the difference 10 feet is entered as minus; at 10,20 the vane read 1,5, the difference 2,5 is entered as plus. In the angles of depression, these terms produce opposite effects on the quantities they are connected with to what they represent; thus at angle 5° 42′ D at 600, a rise or plus 3, this is to be subtracted from the difference of level, it being a fall, which difference has to be subtracted from the previous reduced level. Columns 8 and 9 contain the elevations and depressions *from* the various stations, the differences in column 4 is added to or subtracted from them as the case might be. Column 10 contains the reduced levels, the remaining part of the book being left for observations. By thus calculating and reducing the levels, the section may be plotted exactly in the same manner as if taken with the spirit-level.

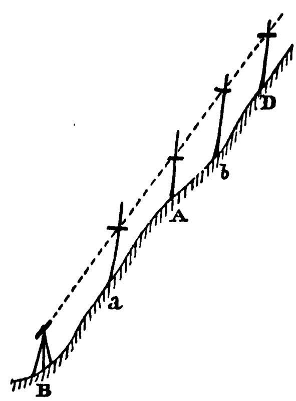
The above method of levelling with the theodolite, may be advantageously adopted in taking trial sections for crossing summits—one section should be carefully taken with the spirit-level, the remainder may be taken with the theodolite—vertical angles being measured to the bench-marks at the extremities; any errors that may have crept into the calculations will then be detected.

If this plan was adopted, how much expense would be saved; comparative sections may then be taken in every direction without the enormous expenses incurred by the present method. Such correct results may not be arrived at certainly as with the spirit-level, but in these preliminary sections, of what consequence is the differing a few feet, when perhaps the *crossing of a summit may be effected thereby at a less elevation by ten times the amount of error.* The theodolite is not put in comparison with the spirit-level for accuracy, but for the above purposes, where a near approximation is all that is necessary, it is presumed it will be found a far more advantageous instrument, as, in some districts, the surveyor might do ten times the quantity of work as with the spirit level.

Of the Method of taking Cross Sections with the Theodolite.

The superiority of the theodolite over the spirit-level will be here manifest. In many cases new roads are projected along the side of a ravine, where it would be scarce possible to plant a spirit-level; in this case the cross sections which would be absolutely necessary, might be taken with the greatest ease and accuracy with the theodolite. At the bottom of the valley, or so far below or above the centre line of the road as you can get a firm footing, plant your instrument as before directed; set the vane on the staff at the same height as the optical axis of the telescope, and set it up exactly on the centre line of the road where you intend taking the cross section, take the vertical angle, and measure the distances; where the ground varies, set up the vane-staff, and note the height at which it is bisected—the method of reduction and plotting will then be the same as in the example given.

The following sketch will illustrate this method of taking cross sections :—



Suppose B A D to be the cross section of the ground, and A the centre line of the road. At B plant your instrument, suppose 4 feet from the ground, set up a staff at A with the vane at the same height, and take the vertical angle; where there is a change in the ground from the general inclination, set up the staff as at *a b* D, slide the vane up until bisected, and measure the distances, the calculations for the bases and differences of level will be the same as in the example given; the section can be plotted to any scale as in common levelling operations.

SECTIO-PLANOGRAPHY:

Or New Method of laying down Sections for Railways and other Public Works, as recommended by Mr. Macneill, and required by the Standing Orders of the House of Commons.

In the previous examples we have given, the plan and section are detached, and totally unconnected with each other. The inconvenience this gave rise to was strikingly manifest in the numerous railway projects that were recently before the legislature. Very few except professional men perfectly comprehend the vertical section; and still fewer, after finding their property on the plan, can refer to the corresponding part on the section,—reference having to be made to scale and compasses. Even to professional men this is a work of trouble and time, and is often inaccurately performed. Was it then probable that a country gentleman or farmer could, on inspection of the plans and sections, understand how their estates or farms would be affected? In many cases it has been proved that the agents of railways, presuming on their ignorance of such matters, have purposely misinformed them for the purpose of gaining their acquiescence. To remedy the inconvenience, uncertainty, and fraud attendant on drawing the plan and section detached, Mr. Macneill contrived the admirable method of connecting them, which we will now describe.

On reference to Plate 6 will be found, in the upper part, a section drawn in the usual manner,—the plan appearing beneath. The strong black line on the plan represents the position of the proposed railway on the ground, and is also considered to represent a vertical section of the rail, the undulation of the ground being marked thereon precisely in the same manner as in the section above:—in fact, the line on the plan (whether straight or curved) is taken as a datum; and after the gradient or rate of clivity is put on the detached section, the heights of embankment or depths of cutting—according as the rail line is above or below the surface—is easily and accurately transferred to, or plotted on the plan. But as the quantity or position of the various cuttings and embankments might not be readily seen on the plan, the cuttings are coloured *red*, and the fillings *blue*: where the rails are intended to be on a level with the surface of the ground, no colour is applied; where the plans and sections are lithographed, to save the trouble of colouring, the cuttings are represented by vertical shade lines, and the fillings by similar horizontal lines. By this method any person, however slightly informed on such subjects, could immediately perceive on inspection of the plan how any particular property would be affected, and whether the railway would pass through it in cutting, embankment, or on a level.

On the Choosing of a Datum Line.

In the commencement of levelling operations, it is necessary (as already explained) to fix on some well-defined mark, as the standard to which the level of each place is referred; from this an imaginary line is drawn, called the datum, which generally has reference to the tides. Some engineers choose for their datum the level of the highest spring tides; others take low water springs. Let us enquire which is the best. The height of high water above the low water constitutes what is called the tide. Many circumstances render it almost impossible to say what is the elevation of high water above the natural surface of the ocean: a strong south-west or north-west wind raises the tides to an unusual height along the east coast of England, and in other places the reverse is the case. In the open ocean, the tides rise to but very small heights in proportion to what they do on the coast. It is also well known that the tides rise in many rivers, channels, bays, and estuaries, to an elevation far above the average height of the *same tide* on more open parts of the coast. In the estuary of the Severn at King's Road, near Bristol, the rise is 42 feet; at Chepstow-on-the-Wye, a small river which opens into the same estuary, about 50 feet;

at Milford Haven, 36 feet; at London, 18 feet; at the promontory of Beachy Head in Sussex, 18 feet; at the Needles in the Isle of Wight, 9 feet; at Weymouth, 7 feet; at Lowestoff, 5 feet; and at Great Yarmouth, 3 or 4 feet only.

In many places the surface at low water is above the natural surface of the ocean; this is the case in rivers, at a great distance from their mouths. This may appear absurd, and is certainly very paradoxical; but it is a fact established on the most unexceptionable authority. One instance will suffice: the low water-mark at spring tide, in the harbour of Alloa, was found by accurate levelling to be three feet higher than the top of the stone pier at Leith, which is several feet above the high water-mark of that harbour. A little attention to the motion of running water will explain this: whatever checks the motion of water in a canal, must raise its surface; therefore a flood tide, coming to the mouth of a river, checks the current of its waters, and they accumulate at the mouth; this checks the current farther up, and therefore the waters accumulate there also: and this checking of the stream, and consequent rising of the waters, is gradually communicated up the river to a great distance; the water rises everywhere, though its surface still has a slope.

It is an extraordinary fact, but some professional men expect the levels of spring tides to correspond in every part of the kingdom; and that the level obtained in a river remote from the sea, but influenced by the tides, will be found to correspond when brought down to the sea. We know of instances where engineers have pronounced sections to be wrong that were taken to the coast, because the high water spring tides did not correspond with that at London. What could be more fallacious,—the difference of the rise of the tides in many of these instances exceeding 20 feet. The level of low water spring tides, which is considered more equable, is now generally taken by engineers as their datum line,—which has also this advantage, that in your section you never run below your datum, which is very troublesome; whereas, by taking high water springs, you are doing so continually; scarce a low track of land in the neighbourhood of the sea or a river but what is on a level, or beneath high water spring tides, and only kept from being flooded by embankment. We should observe, that in taking high or low water as a datum,—if no natural or artificial conspicuous mark exist at exactly the height of the tides,—a good bench-mark must be left in the immediate vicinity; by which means, if not quite certain as to the tide a mean can be taken, it will also be found necessary for future reference. But for extensive operations, we would advise the mean level of the sea to be taken; which (according to M. De la Lande's method, and adopted in the Trigonometrical Survey of England) may be obtained by taking the level of low water, and deducting therefrom one-third of the height to which the tide rises.

ON LEVELLING INSTRUMENTS.

PREVIOUS to giving an account of the various kinds of spirit-levels in use, we would particularly impress on the minds of surveyors and persons who use levelling instruments, only to use those of a superior quality; as an inferior instrument (the correctness of the work entirely depending on the nicety of the finish) will be a never-ending source of error. Let no false economy, for the sake of saving a few pounds, induce you to purchase a common instrument; but whatever kind you purchase, let it be the best: then, with care, your work will always be a credit to yourself, and a satisfaction to your employer.

The staff or stand on which your level is mounted should also be of good substance: a tripod is the best, and made of light fir, and not less than 5½ feet in height when closed. You will then have a good firm mounting for your instrument; the good effects of, in the field, and great advantages over, the skeleton mahogany legs that are generally applied to levels (which you would suppose were made more for show than use), will be very soon apparent. Also, when in the field, the surveyor should be careful, in reversing the instrument, *to turn it only from right to left;* as it often happens (where the level is screwed on to the upper plate), after observing the staff at the back station in attempting to turn it the reverse way to observe the forward staff, that the instrument becomes partly unscrewed from the plate, and consequently its horizontality destroyed. If the staff at the back station should have been removed, it will then be necessary to go back to the last B. M., and commence afresh; but by minding to turn it always from right to left, this will never be the case.

A Description of the various Levelling Instruments, with their Adjustments, and the Method of Using them in the Field.

The Y *Level.*—We have commenced with the Y level (so called from the supports which carry the telescope resembling the letter Y), as being the oldest description of instrument at present in use, but which is now nearly superseded by instruments of far superior and more correct construction. The adjustments of this instrument are easily performed, which may account for the pertinacity with which some people assert its superiority; but on the other hand, they are also as easily deranged. The telescope, in this instrument, is generally made to show objects erect; it is consequently darker and less distinct than the improved instruments, which have telescopes of larger diameter, with fewer glasses, and therefore of more brilliancy.

The first adjustment in this instrument is the line of collimation; to do which, set up the instrument in any position, open the rings which confine the telescope within the Y *s*, and after adjusting for distinct vision, (paying no regard to the spirit-bubble) bisect some well-defined object with the cross wires and clamp the instrument firm, at the same time turning the telescope gently round as it lies on its supports or Y *s*, and observe if the bisection continues during a revolution of the telescope: if so, all is right; if not, you must alter the screws which carry the cross wires or diaphragm until the telescope will revolve in the Y *s*, the bisection remaining perfect. After you have adjusted the line of collimation, you must carefully level the instrument by means of the parallel plate-screws; and when the spirit-bubble remains steady in the centre of the tube (the rings or clips remaining open), you must carefully reverse the telescope end for end, the eye-piece being in the place previously occupied by the object-glass; if the bubble returns to the centre of the tube, it is correct; if not, you must observe the end it retires to, and correct half the error by raising or lowering one end of the bubble-tube, by means of the screws by which it is attached to the telescope, and the other half by the parallel plate-screws which will bring the bubble to the centre of the tube. You must now again reverse the telescope, the object-glass being in the same position as at first. The bubble should now, if correct, return to the centre of the tube; if not, you must alter it, as just directed, until you can reverse the telescope end for end,—the bubble, in each case, returning to the centre of the tube.

The next adjustment is to make the adjusted telescope perpendicular to the vertical axis; or, in other words, to make the instrument revolve on its stand,—the bubble remaining in the centre of the tube the while; if this is not the case, you must raise or lower the milled head-screw (which carries one of the Y *s*, and consequently the telescope and bubble tube) one half the observed error, the other half being corrected as before by means of the parallel plate-screws; and if the bubble will not now remain in the centre of the tube, but retires to either end, it must be repeated until there is no perceptible difference. The instrument will then be in a proper state to observe with; but as the adjustments of the Y level are easily deranged, it is absolutely necessary to examine them frequently,—and as it is easily done, we should recommend it *every morning:* and indeed whatever instrument is used, the surveyor will find it to his advantage to devote a few minutes, every morning before proceeding to work, to examine and rectify if necessary the errors of his instrument.

Troughton's Improved Level.

The improved level is an admirable instrument, capable of taking levels to the greatest degree of accuracy, and is generally constructed to show objects inverted. Its adjustments in the hands of a beginner, or a person only accustomed to the old Y levels, may appear troublesome, tedious, and difficult; but in reality, when fully understood, they are performed with much greater facility, and with far more satisfaction to the operator. The only objection that can be made to this instrument is, that no adjustment is applied to the spirit-bubble tube; so that if, by accident or otherwise, the tube gets deranged or disturbed in the bed in which it is fixed by the maker, the line of collimation must be adapted to it, although no longer remaining in its original situation.

The adjustments necessary for the improved level are the same as those for the Y level, although from the different construction of the instrument they are differently performed. The bubble tube in this instrument has no adjustment, being fixed by the maker in the cell provided for it, which is firmly attached to the telescope. The line of collimation must, therefore, be adjusted to suit the bubble-tube; the most easy and correct method of doing which is to set up the instrument on a tolerable level piece of ground, and set it horizontal by means of the parallel plate-screws; then, at a distance of three or four chains on each side of the instrument, drive a stake firmly into the ground: on these stakes alternately place your staff, and note the graduations bisected thereon by the cross hairs of the telescope. You will thus obtain the true level of two points,—the graduations bisected on the staff being equidistant from the earth's centre, however much your instrument may be out of adjustment.

Then remove your instrument beyond one of the stakes six or eight feet, but the nearer the better, and again read the staffs alternately placed on these stakes, and if the readings give the same difference of level, it shows that the line of collimation is correct; if not, you must alter the collimating screws, raising or lowering the diaphragm, as the instrument looks upward or downward, until the reading on the farther staff (the reading on the nearest remaining the same) gives the exact difference of level, previously ascertained, of the two stakes. You must now ascertain if the instrument will revolve on the staff-head, without a sensible difference in the bubble; if not, you must notice which end it retires to, (as in the adjustments for the Y level,) and correct half the error by the capstan-headed screws at one end of the horizontal bar, and the other half by the parallel plate-screws. If it will not then revolve without changing, you must repeat the process, until it will turn quite round without perceptible difference.

Another method of collimating this instrument is by a pool of still water, in which you must drive two stakes exactly level with the surface, distant two or three chains from each other; then set up your instrument a few feet beyond one of the stakes, and read a staff alternately placed on each, which readings will be exactly the same, if the line of collimation is correct; if the readings are different, you must alter the collimating screws, until the readings are the same on both stakes; or you may set up your instrument exactly over one of the stakes, and measure the height of the telescope above it, which should also be the reading of the staff placed on the other stake, if correct. If the reading is different, you must alter the collimating screws, as before directed, until it reads the same; then adjust the vertical axis to the plane of the instrument, as before directed.

Description, Use, and Adjustments of Mr. Gravatt's Improved Level, commonly called (from its appearance) the Dumpy Level.

This instrument is by far the most perfect for levelling operations; its short length (generally 10 inches only) rendering it less liable to accident, and its adjustments, when perfected, requiring positive violence to derange them. We have a 10-inch level of Mr. Gravatt's construction, which has not required adjusting for twelve months past, although it has been nearly in constant use, with the addition of having been sent per coach, at various times, several hundred miles. The large object-glass applied to this instrument gives it great advantages, as greater brilliancy, and consequently, distinctness in reading the staff, and a much larger field of view: this instrument also inverts objects.

The bubble-tube, as in Troughton's improved level, is above the telescope, but unlike it, has mechanical means of adjustment; there is also a cross bubble attached to the telescope, to assist the operator in setting the instrument up more level by means of the legs than he would be otherwise able to do. The large bubble-tube in this instrument is graduated to tenths of an inch, by which means you can set it up more truly level, and instantly detect the slightest change in the bubble. This instrument may be adjusted in the same manner as described for Troughton's improved level, but much more correct by the method adopted by its talented inventor; as, for example, set up your instrument on a tolerable level piece of ground, and, as directed for adjusting the improved level, drive in two stakes, one on each side of the instrument, at equal distances of one or two chains; then read a staff placed alternately on each, you will then find the true level of two points, however much your instrument may be out of adjustment; then remove your instrument the same or double the distance beyond one of the stakes, and again set it up, and also measure out the same distance beyond the instrument as the instrument is beyond the second stake, and drive in a third. Now read a staff placed alternately on stakes No. 2 and 3; you will then, by adding or subtracting the difference of level between stakes No. 1 and 2, to the difference of level between stakes No. 2 and 3, obtain the true level of three points, viz., stakes 1, 2, and 3, which we will call A, B, and C, and taking stake A as the datum, suppose the difference of level to be as follows :—

Stake A	 0,00	above Datum.
B	 3,63	
C	 2,39	

You must now place your instrument a few feet beyond A, in a line with the three stakes, (but the nearer the better,) and carefully mark, by means of the graduations on the tube, the exact position of the bubble, so that you cannot disturb or alter the instrument, without detecting it. On looking through the telescope the staff placed on A reads 4,74; on B, 0,95; and on C, 1,75. Now had the instrument been in proper adjustment when the reading at A was 4,74, the readings on B and C should have been respectively 1,11 and 2,35; the instrument, therefore, points downwards, the error B being 0,16, and at C, 0,60. Now, was the bubble only in fault, the error at C should be three times that at B, *the distance being three times as* *great;* but 0,16 × 3=0,48 only; there is an error, therefore, of 0,60—0,48=0,12, not due to the bubble. To correct this error, you must raise the cross-wires by means of the collimating screws, and, neglecting the actual error of level, make the error at B only one third at C; after a few trials, the staff at B will read 1,05, and at C, 2,17, the reading at A remaining the same. Now, 1,11—1,05=,06, and 2,35—2,17=0,18; and as 3 × ,06 (the error at B)=0,18 (the error at C), the line of collimation is in perfect adjustment.

What now remains to be done, is to raise the object-glass of the telescope by means of the parallel plate-screws until the reading at C is 2,35, the reading at B will then be 1,11, that at A remaining as at first, then by means of the capstan-headed screws carrying the bubble tube, bring the bubble into the centre of its run. There is still another adjustment, that of making the telescope parallel to its vertical axis, or to make it revolve on the staff-head, the bubble remaining in the centre the while; this is performed in the same manner as described for Troughton's improved level, to which the reader is referred. The operation of collimating upon levels on Mr. Gravatt's construction may appear tedious and complex, but after a few trials it will be easily understood and performed in a few minutes, but when once perfected it will scarce ever need be repeated. But we would nevertheless recommend that the adjustments be always looked to before commencing operations, the few minutes spent in so doing will be amply repaid by the satisfaction produced in *knowing* that your work is correct. In some instruments it is found very difficult to make the bubble retain a central position while being turned round on its axis, or, as it is generally expressed, to make the instrument reverse, the operator must in this case repeatedly try to correct it, in the manner previously directed for making the telescope parallel with the vertical axis. But if after many trials the bubble will not remain in the centre of the tube, while the instrument is reversed, it must be brought to that point by means of the parallel plates at each reading of the staff.

On Instrumental Parallax.

Instrumental parallax is often the cause of great errors being committed, and more especially in levelling operations—in fact observations of any kind, whether in surveying or levelling, are worthless if parallax exists. The causes of parallax are easily explained when the method of remedying it will immediately suggest itself.

The rays of light moving in straight and parallel lines (although not actually the case, it may here be considered so without sensible error) are immediately on coming in contact with the object-glass of a telescope bent on one side and turned from their previous straight course, converging to a point which is the focus, an image of the observed object being there formed; and for the purpose of distinguishing this object, an eye-glass of magnifying powers is applied to the telescope.

To obtain a proper view of this image formed at the focus of the object-glass, the focus of the eye-glass should be at the same point, the cross-wires of the telescope appearing at the same time perfectly clear and sharp; if not *it produces parallax*, which is at once detected on looking through the telescope and bisecting any object, the cross wires not remaining in contact with the object, but apparently moving as you move your eye, up or down, or on either side, rendering it impossible to ascertain the correct bisection. To remedy this it is necessary to move the eye-glass a very little until you obtain a clear and well-defined view of the cross wires, then turn the screw attached to the telescope which communicates motion to the slide carrying the eye-piece and cross-wires, until you obtain a distinct view of the object, the focal point of the eye-piece will now coincide with that of the object-glass on whatever part of the optical axis it falls (the focus of the object-glass varying according to the distance of the object), and on looking through the telescope at a staff, or any well-defined object, the observer will obtain a clear and distinct view of the object and the cross wires, apparently attached, and appearing equally distant. The proof of the parallax no longer existing, will be in the moving about of the observer's eye and no displacement taking place. The whole sum, substance, and correction then, of the perplexing parallax, consists in a very slight movement of the eye-glass of the telescope, which must be further continued until the parallax no longer exists.

Of the Cross Wires of the Diaphragm.

It will often happen from changes in the state of the atmosphere, that the cross wires will break. To repair this the surveyor should loose the collimating screws, and take out the diaphragm, then draw out the finest film of silk from any garment of that material you may have, and pass a little gum water over it, let it dry, and gum or glue it on to the diaphragm; if you should neither have glue or gum, you may fix it on the diaphragm by making a small cut in the sides with a knife just sufficient to raise the metal, lay the film of silk in the notch, and close it. Replace the diaphragm within the telescope, and adjust for use as before directed.

Levelling Staves.

There are various descriptions of staves for levelling operations, the oldest of which is that with the sliding vane, moveable by the person holding it with a cord passing through pulleys at top and bottom, the staff being in one piece of about 12 feet in length, graduated on the face into feet and inches, or feet and decimals. There is also another kind of vane-staff graduated similar to the above, but the staff itself, instead of being in one piece, is divided into two or three sliding pieces of about five feet each, the vane in this case being moved by the hand over the first division. When the observation requires that the vane should be higher than that, it is effected by leaving it at the summit of the first division of the staff, and sliding it up on the second, thereby reaching 10 feet; if this should not be high enough you slide up .the second in like manner on the third until you reach the required height. The reading on this staff is by an index on the side; as for example, slide the vane to the top of the first division it will be five feet, then slide the division up on the second two feet, the bisection being perfect, the reading on the index at the side of the staff will be two feet, which added to the first division of five feet, will be equal to 7 feet, the height of the vane from the ground; in like manner if you slide the second division up on the third 2 feet, the height would be 12 feet, but these staves are now rarely used except in remote districts where improvements have not penetrated.

The staves now in general use (the invention of William Gravatt, Esq.) are without any vane, the graduations, feet, tenths, and hundreths, being sufficiently distinct to enable the observer to note the reading from the instrument, and with the powerful telescopes now applied to spirit-levels, the graduations can be distinctly and accurately noted at a distance exceeding ten chains, thereby saving much time, and obtaining more accurate results. The mechanical arrangements of Mr. Gravatt's staves are very simple; they are in three pieces, with joints similar to a fishing-rod, and when put together for use, form staves 17 feet in length, but when asunder pack very conveniently for carriage. There are several modifications of Mr. Gravatt's stave, differing in their mechanical arrangements only, all retaining the main object, viz. having the graduations sufficiently distinct to enable the observer to read off the quantities himself. The person who has most improved on Mr. Gravatt's invention is Mr. Sopwith of Newcastle, whose staves are very convenient; the graduations are nearly the same, but the decimal parts of the feet are figured, the subdivisions also are more minute; when closed it is only five feet in length, but drawing out similar to a telescope to 15 feet, a spring catch retaining each joint in its place.

A staff has been contrived by the author, which will be found more convenient than any that has appeared before the public; one great fault with the improved stave is, that in reading off with an inverting telescope (which nearly all levels have now, for reasons before explained) you are very liable to error from the figures appearing upside down, you are consequently apt to mistake one figure or division for another, often leading to serious errors. To remedy this inconvenience *the figures on this stave are inverted*, whereby, when viewed through an inverting telescope, they appear in their natural order, doing away with the confusion and uncertainty hitherto existing, and enabling the observer instantly to note the reading with expedition and accuracy, altogether making a considerable difference both as to the quantity and accuracy of the work. There are also various mechanical arrangements in this staff differing greatly from the preceding; when closed for carriage it is only 5 feet in length, but opens for use to 15 feet. A peculiar shoe or foot is attached to this stave, which the author considers of some importance:—practical men are aware of the irremediable errors committed through the carelessness of stave holders; when the face of the stave is turned from the last forward station to become the next back, an error of an eighth of an inch or more is often occasioned through the clumsiness of the holder in pressing the stave into the ground, or lifting it up carelessly with clods of soil adhering to it, and again putting it down with the face reversed; the errors committed in this way are greater than are generally imagined. Many surveyors attempt to remedy this by putting a coin or some flat substance beneath the stave, but generally the stave holder is too careless or lazy to attend to it, and the staff is in most instances placed on the ground without anything beneath it. Mr. Simms has contrived an iron tripod for resting the staffs on, which in a great measure removes this source of error, but is very troublesome for the man to carry. The description of shoe the author has applied to his staves will allow the face to be turned in any direction, without in the least disturbing that part resting on the ground, whereby this evil is effectually remedied.

The stave should be pressed on the ground at each station, and on turning the face in any direction, not the slightest change in the level of the stave will take place.

ON THE SETTING OUT OF RAILWAYS.

We will here give a few directions, which are necessary to be observed in the carrying of a line of railway into execution. Previous to the execution of the works, it becomes necessary to have the centre line of the road very accurately determined; and a stake should be firmly driven into the ground at about every chain's length, or at each 100 feet as may be advisable; which centre line should be afterwards carefully levelled and a sight taken at each stake, which then becomes as so many bench-marks. These stakes should be numbered consecutively; and when the section is plotted, and the gradient (or rate of clivity) put on, it will at once show you the height of embankment or depth of cutting at each stake. The requisite widths (which will depend on the slopes and the embankment or cutting) should also be carefully put in, at one view showing the proprietor of the ground the quantity of his land that you require, and the damage he will sustain by severance or otherwise,—which will be more satisfactory to him and all parties concerned than any number of plans.

To set out a straight line of railway is not a difficult matter; yet, to do it correctly, a good theodolite is necessary to ensure a straight line, and all obstacles impeding a clear view should, if possible, be removed. You may then, with the assistance of your theodolite, set out a perfectly straight line for any distance, by pursuing the directions we have previously given for measuring a base line.—(See Parish Surveying.) If any buildings should chance to be in the way, and you cannot see over them, you may easily and accurately pass round to the opposite side by forming an equilateral triangle, as already pointed out in the passage referred to above. In a recent extensive survey in which we were engaged, while measuring the bases and tye-lines, we unavoidably came on many buildings; but, by pursuing the above method, we passed round them without the least difficulty. One case in particular may be worth notice. In measuring the principal base (which passed over two ranges of hills and the intervening valley), we had a very conspicuous forward object; but in passing through the valley, our line came directly on a very thick wood of considerable extent, through which it was quite useless attempting to pass: we therefore set out an equilateral triangle, the sides of which were each a quarter of a mile; and on coming to the opposite side of the wood, and setting off the supplementary angle of 120°, the instrument exactly bisected the first observed object: the maximum error on this line (which was more than 2½ miles in length) did not exceed five links. But to return to the point in question: when the line of railway changes either to the right or left, it cannot do so at an angle, but gradually; forming a curve line which is a part of a circle, the radius being seldom less than a mile. It must be evident that this circle cannot be struck from a centre; means must therefore be adopted for finding certain points on this curved line, to which points straight lines may be drawn, which will approximate so closely to a regular curve as to be sufficiently correct for practical purposes: although, when laying the rails for the permanent way, straight lines are inadmissible, and fresh points on the curve between these former ones must be found through which a regular curve can be drawn, and to which curves the railway bars are generally brought previous to laying, as no combination of straight lines will produce a curve sufficiently regular for the purpose intended.

A straight line, connected with a curve, should be a tangent to it; and two curves joined or connected together should have a common tangent, but they may turn different ways at the point of contact, forming a double curve, or curve of contrary flexure, similar to the letter S.

The methods pursued in laying out curves are various; but the following, as communicated by Mr. D. J. Henry, C.E., of Dublin, and successfully practised by him, appears to us to be the most easy and correct method we are acquainted with:—

When the intermediate ground between the straight lines is level, you may assume any radius at pleasure, provided it be sufficiently long to connect the lines with a convenient degree of curvature; then the points of contact measured from the angle of meeting of the two lines both ways will be found thus:—

As sine of half the angle of meeting
Is to cosine of said angle,
So is the assumed radius
To the distance of the required point of contact from the angle of meeting.

Next, when the nature of the ground is such that the curve must pass through a certain place, in which case the point of contact is assumed, and the radius will be found by the converse of the above statement, thus:—

As cosine of half the angle of meeting
Is to sine of said angle,
So is its distance from the assumed point of contact
To the radius required.

Now to lay down the curve, take the nat. sine of 1° and multiply it by the radius in chains, and lay off the product from the point of contact as tangent in continuation; then at the extremity lay off at right angles to it on the concave side of the curve, a distance equal to the radius diminished by product of the radius and the nat. cosine of 1°, and that will determine a point in the curve. Now as the angle at the circumference standing on a chord of

1° is 30′, and the exterior angle made by a second chord of 1° and the first chord produced will be double thereof,* or 1°, we have the length of the next line on the first chord produced, and its corresponding set-off from the following proportions:—

As radius of the tables
Is to the cosine of 1°,
So is the chord of 1° in the given circle
To the distance to be measured on the first chord produced. And

As radius of the tables
Is to sine of 1°,
So is the chord of 1° in the given circle
To the set-off.

Thus, let the radius of the circle be 1 mile or 80 chains, take the $\angle\, a\, r\, x$ (see diagram Plate 8) = 1°, then the nat. sine thereof will be .017452, which multiplied by 80 will give $x\, z$ equal to 1 chain

* We have made some alterations in the above, but fearing the method might not be quite understood, we add the following Note:—

The principle of the method consists in this, that if successive equal chords be taken in a circle, the angle made by the produced part of any chord with the adjacent chord is equal to the angle which the chord subtends at the centre of the circle. Thus in the diagram, Plate 8, let $a x = x n$, then the angle $m x n =$ the angle $a r x$, for the angle $m x n =$ angle $x a n +$ angle $x n a$; but each of them = half the angle $a r x$, therefore, &c. Now from the point n, let fall the perpendicular $n m$, then $x m$ is the cosine of the angle $m x n$ or $a r x$ to the radius $x n$ or $a x$, and $m n$ is the sine of the same angle to the same radius; or conversely, if $x m$ be taken in the chord $a x$ produced, equal to the cosine of the angle $a r x$ to the radius $a x$; and if $m n$ be taken perpendicular to $x m$ equal to the sine of the same angle to the same radius, the point n thus determined is a point in the circle; the same values applied to $x n$ produced, determines the next point in the curve.

39.6 links, equal to $y\ a$, *the distance on the tangent*, and the nat. cosine of 1° is .999848, which taken from radius of the tables will leave 000152, the versed sine of 1°, which multiplied by 5280 (the number of feet in one mile), will give .803560 feet or 9.6 inches, for the numerical value of $a\ z = y\ x$ *the first set-off* at y. The chord of 1° is equal to 2 × nat. sine 30′, and therefore the chord ax or $xn = 2$ × nat. sine 30′ × 80 in chains = 139,63 links. Then say—

As radius of the table
Is to cosine 1°,
So is 139.63 links
To $m\ x$, the distance to be set off in a direct line with the chord $a\ x$. And

As radius of the tables
Is to sine 1°,
So is 139.63 links
To $m\ n$.

At the point m lay off $m\ n$, already found, and n will be another point in the curve; and thus continue to lay off the distance $x\ m$ in a line with the last chord, with its corresponding set-off at right angles to its extremity, and you have the curve complete.

Manner of putting in the Widths.

After the centre-line is staked out, the section taken, and gradient put on, you can easily determine the widths that will be required on every part of the line; having the embankment or cutting at regular intervals where the stakes are driven, it will be only necessary to multiply the height or depth by double the slope, and add the width of roadway and ditches, which will be the extreme width. In plate 7, the first figured height on the section is 17 feet; the width of roadway on the plan, 28 feet, with 12 feet on each side for bank and ditch, and the slopes 2 to 1; now, $17 \times 4 = 68 + 28 + 24 = 120$ feet the width set off that point; and in this way were the other widths calculated and put in.

Of Gradients, or Rates of Clivity, showing the method to be pursued in forming an Embankment or Cutting, so as to produce one regular Incline.

In the constructing of roads, but more especially rail-roads, it is essential, as far as circumstances will permit, that a level be obtained, but for any considerable distance this is generally impracticable; it then becomes necessary to surmount the inequalities of the ground, by means of regular inclines, which are, however, kept as near a level as possible, due regard being paid to economy. The method pursued in regulating the quantity of embankment or cutting, so as to produce a regular rate of clivity, is what we shall here describe:—*Divide the difference of level by the distance in chains: the quotient will be the rise or fall at each chain's length*; thus, in Plate 7, the rate of clivity is laid on the section in the first instance, after the rate of 16 feet per mile; take the distance, 1 mile, with the rate of clivity as above; then, 1 mile or 80 chains ÷ 16, (the rate of clivity) = ,2, showing that a difference of ,2 at each chain's length will form a rate of clivity equal to 16 feet per mile. To apply this to practice, set up your spirit-level at either end of the cutting or embankment, and each chain's length therefrom, must show a difference of ,2 to produce the requisite rate of inclination. The theodolite might be employed where the rate of clivity is very great, by setting it up at an ascertained height, and taking the vertical angle as already explained in our directions for levelling with that instrument. The angles answering to the various rates of inclination will be found at the end of this treatise.

The Forming of Slopes.

Embankments or cuttings are generally brought to one uniform slope, except where the strata in deep cutting is found to vary; when this is the case, some portion will often stand at a much greater inclination than others; when so, a ledge, or benching, as it is termed, is left where the angle of the slope changes. As already explained in our directions for setting out a railway, the widths would be put in when the centre line is set out; then, after excavating to the required depth, it becomes necessary to bring the slopes to the degree of inclination previously determined on. Various kinds of levels are occasionally employed, but that in most common use is of wood, made to the required slope, and set up perpendicular by means of a plumb line. A convenient and portable instrument for this purpose is the batter-level, or clinometer, which is a small quadrant, with an attached bar, to which a rod is affixed when in use; the quadrant has an index carrying a spirit-level, which is moveable round the centre of the instrument; when in use, the rod is laid on the slope, and the index moved by the hand, until the bubble assumes a central station in the tube, the angle denoted by the index will be the inclination. The ratios of the slopes for the various degrees of inclination will be found at the end of this treatise.

It should be observed, that when speaking of slopes, as 2 to 1, 1½ to 1, ⅙ to 1, &c., the base is always first; two to one signifies, that for each foot perpendicular, a base of two feet is required, or, what is the same thing, that it batters two feet; one sixth to one means, that for each foot perpendicular, a base of 2 inches will be required, or that it will batter 2 inches.

On the Method of Calculating Earth-work.

There are various methods for calculating earth-work, but certainly none so correct as the prismoidal formula adopted by Mr. Macneill. It would be useless our demonstrating this, as the reader will find every information by referring to Mr. Macneill's Tables; and as we suppose no one would go through the tedious process of calculating by the formula, we will merely direct the student in what manner to arrange the quantities on a section, so as to calculate the contents by the tables above mentioned.

In Plate 7, which is the contract section, the quantity of cubic yards in the embankment from the road at B to the road at C is 128.795,6180; the method pursued in getting this quantity, is to take a portion of the section so far as the inclination of the ground is continuous; slight undulations of the surface being equalized in the same manner as directed for calculating superficies; the first portion taken was 510 feet in length, 17 feet in height at one end, and on a mean line being drawn, was found to be 21 feet at the other end, the base being 28 feet, and the slopes 2 to 1:—the contents found by table 29 is 23.737,2360 cubic yards for that portion of the embankment between the two first figured heights; the next portion taken was 400 feet in length, extending from the second to the fourth figured height, the contents of which is 22.617,3600 cubic yards; in this way were taken the several portions of 570 feet, 2185 feet, and 1670 feet which finished up to the road, the respective quantities for these distances being 24.545,6820 cubic yards, 39.708,4420 cubic yards, and 18.186,9680 cubic yards, the whole of which being added together, will make the total quantity of embankment in this portion of the railway 128.795,6880 cubic yards, as given before.

TABLES.

No. 1.

Reduction in Links and Decimals upon each Chain's Length for the following Vertical Angles

Angle.	Reduction.	Angle.	Reduction.
3° 0′	,137	11° 45′	2,095
3 15	,161	12 0	2,185
3 30	,187	12 15	2,277
3 45	,214	12 30	2,370
4 0	,244	12 45	2,466
4 15	,275	13 0	2,553
4 30	,308	13 15	2,662
4 45	,343	13 30	2,763
5 0	,381	13 45	2,866
5 15	,420	14 0	2,970
5 30	,460	14 15	3,077
5 45	,503	14 30	3,185
6 0	,548	14 45	3,295
6 15	,594	15 0	3,407
6 30	,643	15 15	3,521
6 45	,693	15 30	3,637
7 0	,745	15 45	3,754
7 15	,800	16 0	3,874
7 30	,856	16 15	3,995
7 45	,913	16 30	4,118
8 0	,973	16 45	4,243
8 15	1,035	17 0	4,370
8 30	1,098	17 15	4,498
8 45	1,164	17 30	4,628
9 0	1,231	17 45	4,760
9 15	1,300	18 0	4,894
9 30	1,371	18 15	5,030
9 45	1,444	18 30	5,168
10 0	1,519	18 45	5,307
10 15	1,596	19 0	5,448
10 30	1,675	19 15	5,591
10 45	1,755	19 30	5,736
11 0	1,837	19 45	5,882
11 15	1,921	20 0	6,031
11 30	2,008		

No. 2.

Table of Slopes and Inclines for the following Vertical Angles.

Angle.	To one perpendicular.	Angle.	To one perpendicular.
0° 15′	229	8° 8′	7
0 30	115	8 45	6½
0 45	76	9 27	6
1 0	57	9 52	5¾
1 15	46	10 18	5½
1 30	39	10 47	5¼
1 45	33	11 19	5
2 0	28	11 53	4¾
2 15	25	12 32	4½
2 30	23	13 15	4¼
2 45	21	14 2	4
3 0	19	14 55	3¾
3 15	18	15 56	3½
3 38	17	17 6	3¼
3 35	16	18 26	3
3 49	15	19 59	2¾
4 6	14	21 48	2½
4 24	13	23 58	2¼
4 45	12	26 34	2
5 0	11½	29 44	1¾
5 12	11	33 42	1½
5 27	10½	38 40	1¼
5 42	10	45 0	1
6 0	9½	53 8	¾
6 21	9	63 28	½
6 43	8½	75 58	¼
7 7	8	78 41	⅕
7 36	7½		

TABLES.

No. 3.

Of the difference of the Apparent and True Level for distances in Feet.

Distances in Feet.	For Curvature.	For Refraction	For Curvature & Refraction.
	Correction in Decimals of Feet.		
100	,00024	,00004	,00020
150	,00054	,00008	,00046
200	,00096	,00013	,00083
250	,00149	,00021	,00128
300	,00215	,00031	,00184
350	,00293	,00042	,00251
400	,00383	,00055	,00328
450	,00484	,00069	,00415
500	,00598	,00085	,00513
550	,00724	,00103	,00621
600	,00861	,00123	,00738
650	,01010	,00144	,00866
700	,01172	,00167	,01005
750	,01345	,00192	,01153
800	,01531	,00219	,01312
850	,01728	,00247	,01481
900	,01938	,00277	,01661
950	,02159	,00308	,01851
1000	,023[illegible]2	,00333	,02059
1050	,00	,00377	,02261
1100	,02895	,00414	,02481
1150	,03164	,00452	,02712
1200	,03445	,00492	,02953
1250	,03738	,00534	,03204
1300	,04043	,00578	,03465
1350	,04361	,00623	,03738
1400	,04689	,00670	,04019
1450	,05030	,00719	,04311
1500	,05383	,00769	,04614
1550	,05748	,00821	,04927
1600	,06125	,00875	,05250
1650	,06514	,00931	,05583
1700	,06914	,00988	,05926
1750	,07327	,01047	,06280
1800	,07752	,01107	,06645
1850	,08188	,01027	,07161
1900	,08637	,01234	,07403
1950	,09098	,01300	,07798
2000	,09570	,01367	,08203

No. 4.

Of the difference of the Apparent and True Level for distances in Chains and Links.

Distances in Chains & Links	For Curvature.	For Refraction	For Curvature & Refraction.
	Correction in Decimals of Feet.		
100	,00010	,00001	,00009
150	,00024	,00003	,00021
200	,00042	,00006	,00036
250	,00065	,00009	,00056
300	,00094	,00013	,00081
350	,00128	,00018	,00110
400	,00167	,00024	,00143
450	,00211	,00030	,00181
500	,00261	,00037	,00224
550	,00315	,00045	,00270
600	,00375	,00054	,00321
650	,00440	,00063	,00377
700	,00511	,00073	,00438
750	,00586	,00084	,00502
800	,00667	,00095	,00572
850	,00753	,00108	,00645
900	,00844	,00121	,00723
950	,00940	,00134	,00806
1000	,01042	,00149	,00893
1050	,01149	,00164	,00985
1100	,01261	,00180	,01081
1150	,01378	,00197	,01181
1200	,01501	,00214	,01287
1250	,01628	,00233	,01395
1300	,01761	,00252	,01509
1350	,01899	,00271	,01628
1400	,02043	,00292	,01751
1450	,02191	,00313	,01878
1500	,02345	,00335	,02010
1550	,02504	,00358	,02146
1600	,02668	,00381	,02287
1650	,02837	,00405	,02432
1700	,03012	,00430	,02582
1750	,03192	,00456	,02736
1800	,03377	,00482	,02895
1850	,03567	,00509	,03058
1900	,03762	,00537	,03225
1950	,03963	,00566	,03397
2000	,04169	,00596	,03573

No. 5.

Of the difference of the Apparent and True Level for distances in Miles.

Distances in Miles.	For Curvature.	For Refraction	For Curvature & Refraction.
	Correction in Decimals of Feet.		
¼	,0417	,0060	,0357
½	,1668	,0238	,1430
¾	,3752	,0536	,3216
1	,6670	,0953	,5717
1½	1,5008	,2144	1,2864
2	2,6680	,3811	2,2869
2½	4,1688	,5955	3,5733
3	6,0030	,8561	5,1469
3½	8,1708	1,1673	7,0035
4	10,6720	1,5246	9,1474
4½	13,5468	1,9295	11,5773
5	16,6750	2,3821	14,2929
5½	20,1769	2,8824	17,2945
6	24,0120	3,4303	20,5817
6½	28,1809	4,0258	24,1551
7	32,6830	4,6690	28,0143
7½	37,5190	5,3599	32,1591
8	42,6880	6,0997	36,5883
8½	48,1910	6,8844	41,3066
9	54,0270	7,7181	46,3089
9½	60,1971	8,5996	51,5975
10	66,7000	9,5286	57,1714
11	80,7070	11,5296	69,1774
12	96,0480	13,7211	82,3269
13	112,7230	16,1033	96,6197
14	130,7320	18,6760	112,0560
15	150,0750	21,4393	1 8,6357
16	170,7520	24,3931	146,3589
17	192,7630	27,5376	165,2254
18	216,1086	30,8727	185,2359
19	240,7870	34,3981	206,3889
20	266,8000	38,1143	228,6857

Addenda.

When railway surveys are completed, the contents of each enclosure through which the line passes should be written within it, with the description of land, as arable, pasture, &c., also the owner and occupier's names, which will be found infinitely superior to having the usual detached reference-book. In the reduced plans for depositing, &c., a detached reference-book is indispensable. The method of computing the contents is by triangles, in the manner previously described: that required for the railway may generally be computed as parallelograms.

In the description of field-books for levelling, we should have mentioned that an assistant always chains the distance, giving to the principal the chainage at each point where the staff is set up. A custom is prevalent with some people, in place of inserting the chainage to attach numbers or letters to each sight, which refer to another book kept by the assistant who chains the distance—in which, to the corresponding number or letter, is inserted the distance; but any error or omission on the part of the principal or assistant, involves the whole in inextricable confusion, and it becomes worthless. We have seen many instances of ruinous errors being committed, entirely from this method of keeping the field-book; and we would urge those persons who are in the habit of keeping their book in this manner, to abandon it before they have reason to be sorry. In the deposit plan for railways, &c.,

although the section is drawn on the plan as explained in our description of Sectio-Planography, yet the usual detached section is always required for engineering purposes.

In taking horizontal angles with the theodolite, the object is bisected by the vertical wire; but in taking vertical angles, the bisection is made with the horizontal wire: the latter is always the case in levelling instruments, the former serving to show the operator when the staff is held perpendicular. A micrometer scale is sometimes attached to surveying as well as levelling instruments, in place of the cross-wires. This is a fine slip of mother-of-pearl, or wire strained across the diaphragm in regular divisions; the object is to measure distances, which can be done thus:—level your instrument, and measure out various distances, at each of which set up the staff; note in your book how many of the divisions on the micrometer scale the staff subtends. To apply this in practice, on the staff being planted at any distance from your instrument, refer to the table, and the corresponding division to that subtended in the scale will give the required distance. This method, however, has not much pretensions to accuracy, and cannot at all be practised in windy weather; but it might always be advantageously employed to plant the staff at equal distances.

LONDON:
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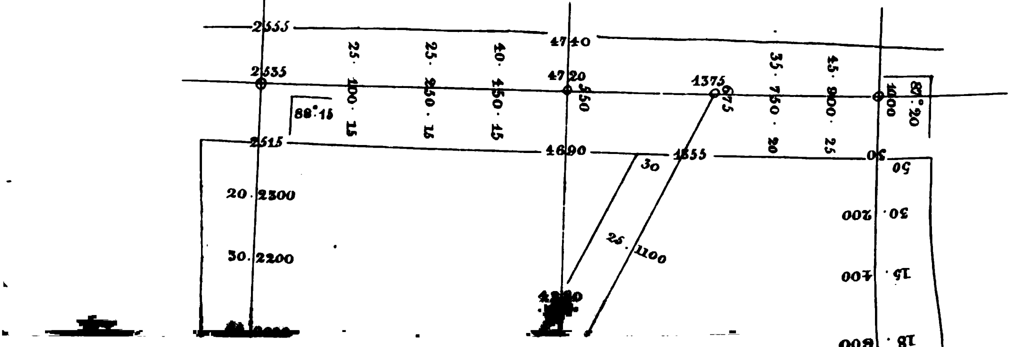
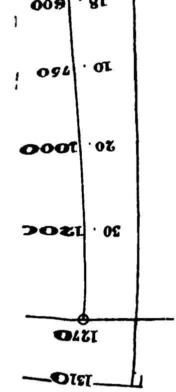
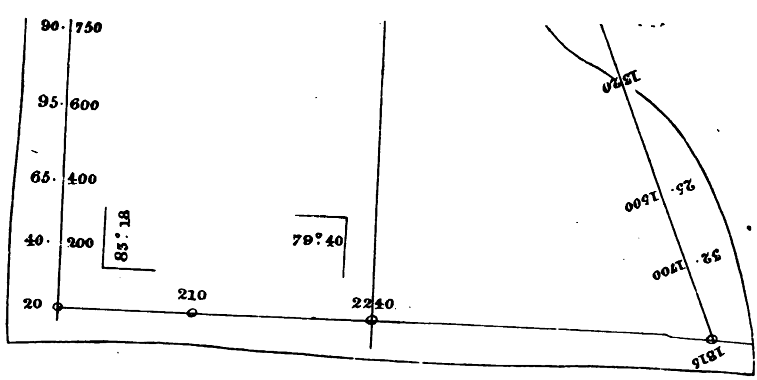
FIELD – BOOK. *Pl. 1.*





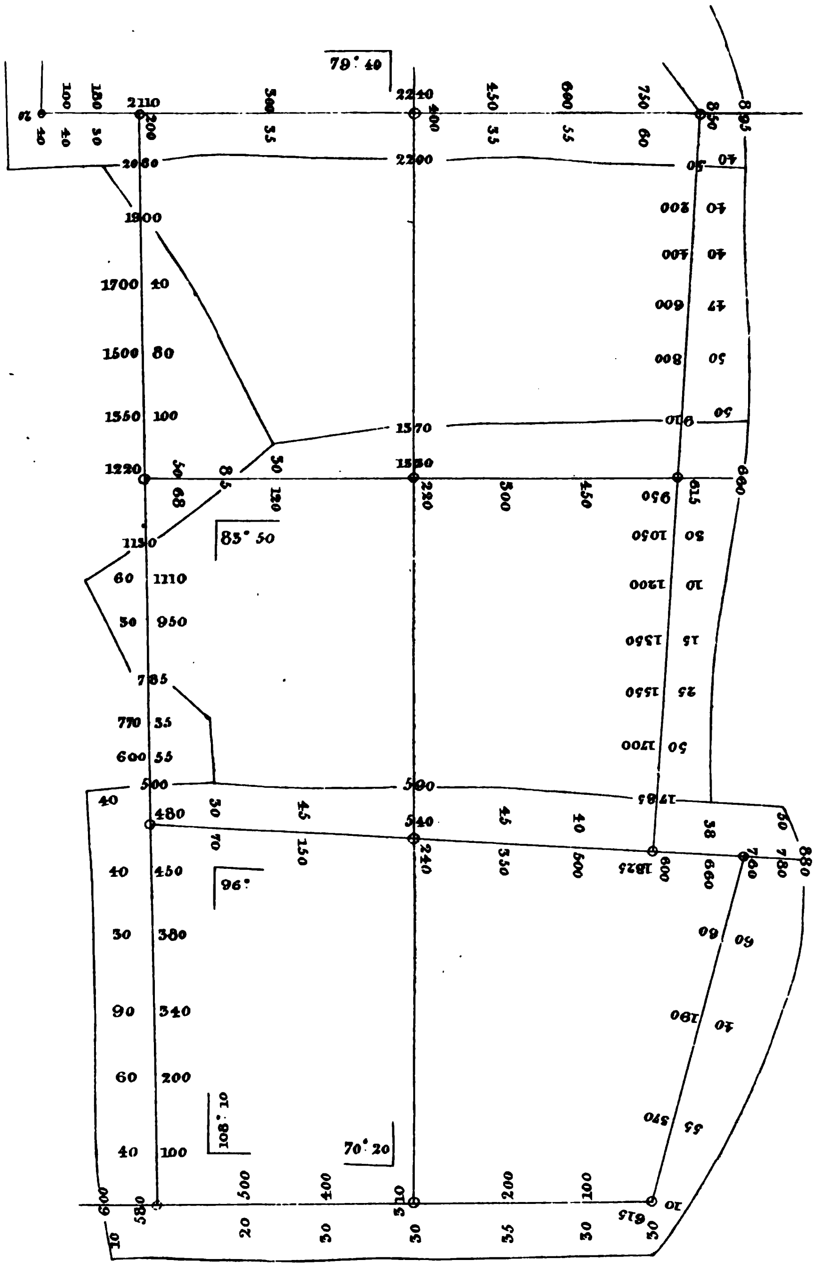
ERRATA.

Preface, 1st line, *for* " suggested itself" *read* " occurred."
Page 21, last line, *for* " Plate 1 " *read* " Plate 5."
Page 22, last line, *the Plates referred to are* " 1 and 2."
Page 24, " Plate 7 " *is here referred to.*
Page 62, line 11 from bottom, *for* " 31 perches " *read* " 21 perches ;" and at line 10 from bottom, *for* " 15 perches " *read* " 5 perches.
Page 92, line 8 from bottom, 4th word from left-hand, *add* " the square of the "
For " Plates 1, 2, 3, 4," *read* " Plates 4, 3, 2, 1."

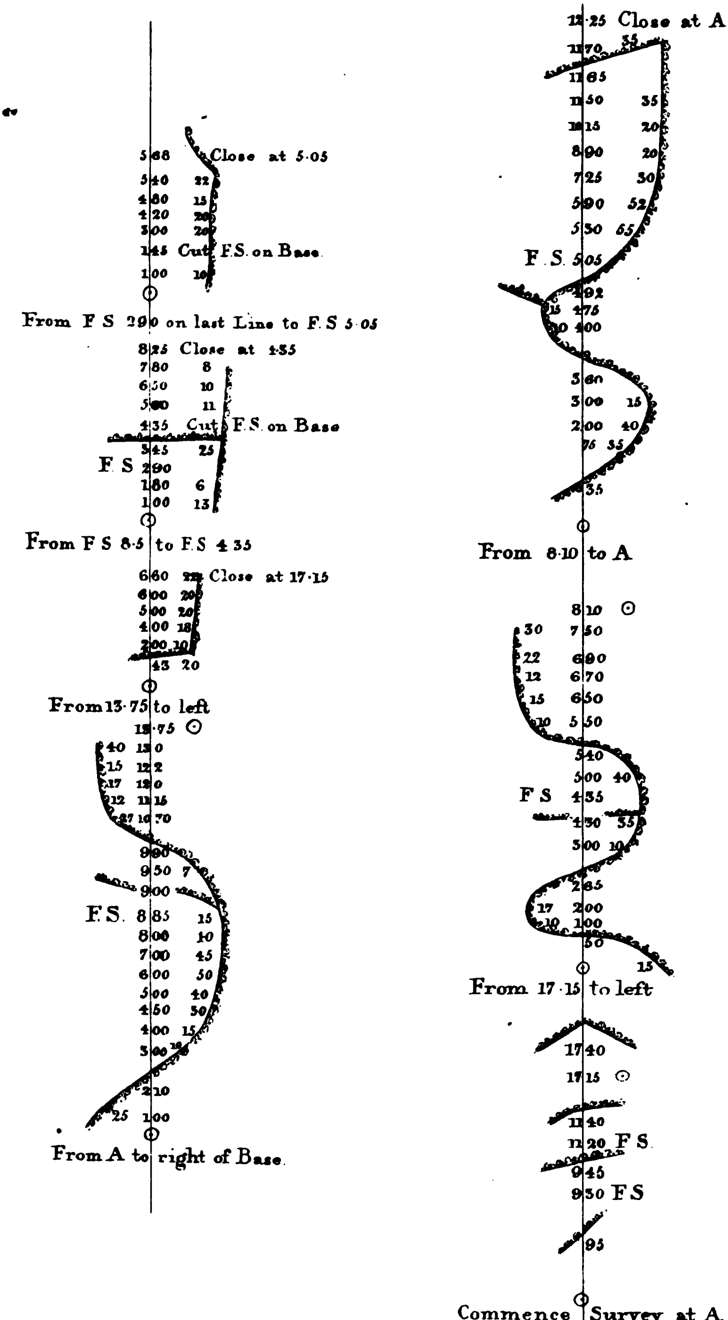


FIELD — BOOK

Pl. 2.



F. J. Havenscroft, Lith. 18, Took's Court, Chancery Lane.



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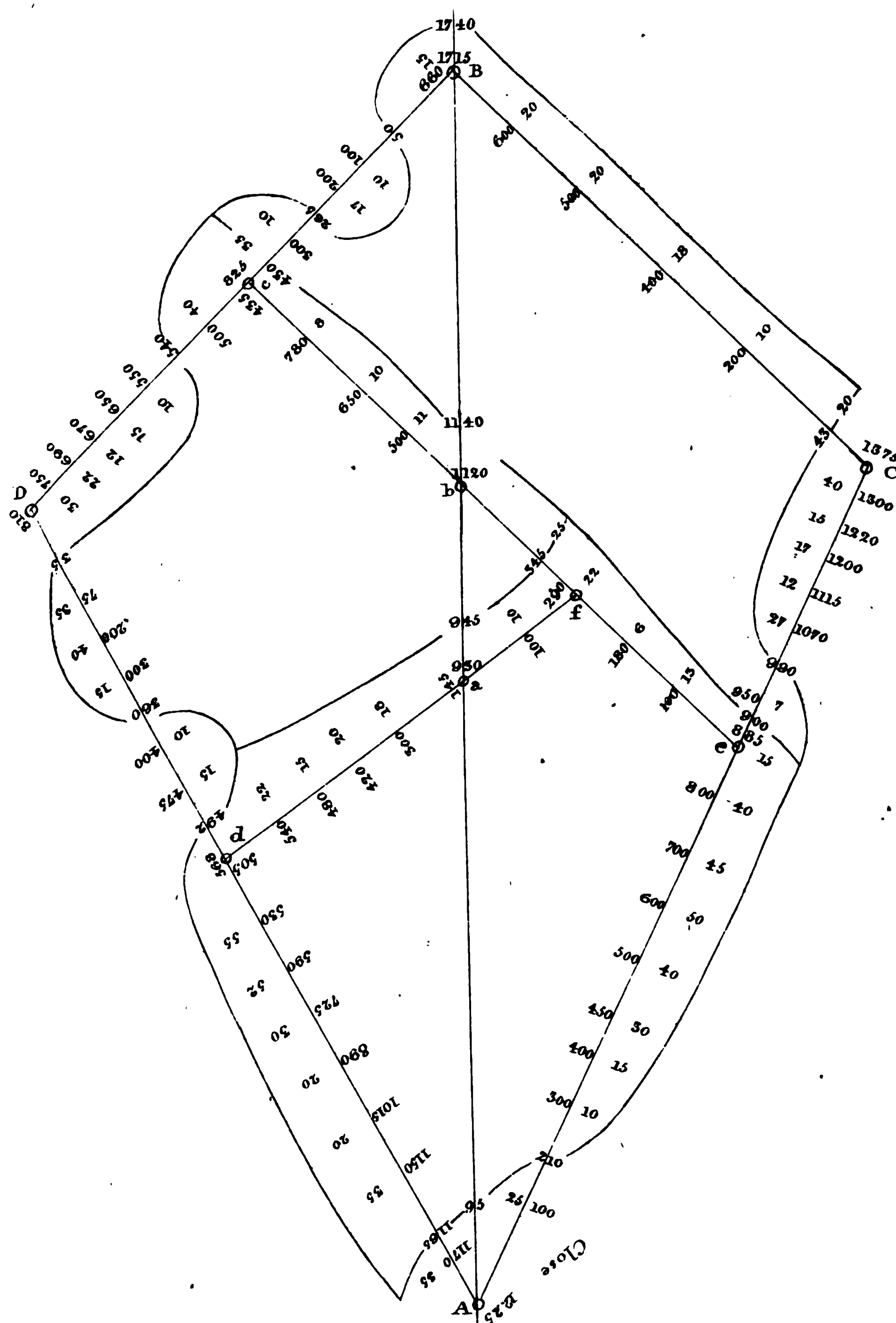
F I E L D – B O O K. *Pl. 4.*



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